FRUITS OF INDIA
TROPICAL AND SUBTROPICAL

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PREFACE

The need for a book of this kind was deeply felt by me in the recent years, in view of the marked advances in fruit production technology especially in the last two decades and the lack of up-to-date compilation on the various aspects of cultivation of major fruit crops of tropical and subtropical parts of the world. The large volumes of research works that have been done, and the information accumulated over the years necessitated the need for immediate publication of a good up-to-date text book on tropical and subtropical fruits to keep the readers conversant with the current literature and development in the subject.

This book is a comprehensive, well-prepared work, covering various aspects of culture of all the major tropical and subtropical fruits, written by author(s) who are well-known in the field of pomology. Recent literatures regarding production technology and crop improvement and other relevant aspects have been incorporated. In fact, efforts have been made to provide the widest possible information and knowledge on the subject.

The book is designed to meet the requirements of research workers and students alike, engaged in horticultural teaching and research work. It will be useful to extension workers and to those engaged in fruit processing industry.

The editor wishes to express his sincere gratitude to the contributors for their effort and care with which these chapters have been prepared. Thanks are due Dr. S. K. Mitra, and Dr. S. C. Maity, my colleagues and Mr. R. S. Dhua, Research Fellow in the Department for their substantial help during the process of publication, to Mr. B. Mitra of Messers Naya Prokash who has taken keen interest in the publication of this book and to Mrs. K. Neyogi for her help and assistance.

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1

HISTORY IMPORTANCE AND SCOPE OF TROPICAL AND SUBTROPICAL FRUITS IN INDIA

P. N. BAJPAI, H. S. SHUKLA and O. P. CHATURVEDI

1.1 Brief Historical Account

Fruits have been the man's food from time immemorial. There is mention of fruits in the vedic literature, religious books and testaments. The earliest fruit grown by man is said to be the date-palm which finds its record as early as 7000 B.C. Pomegranate, fig, olive, grapes have been mentioned in ancient literature. The first book in the world on fruit culture appears to be on litchi written in the year 1056 A.D. The mango is believed to be grown for more than 4000 years. In India, horticulture was an important avocation during the 4th century B.C. and also in pre-Buddhist period. The mango, banana, fig, grape and date-palm were grown during that period. There is record of fruits in *Charak Samhita* and *Sushruta Samhita*, the medical works in Sanskrit. Emperor Babar recorded in his memoirs the presence of some citrus fruits in the early 16th century. Orcharding was the hobby of the Mughals and the 'Lakh Bagh' in Bihar can be cited as an example of it. The pineapple and papaya were introduced into India by the Portuguese. Phalsa was first reported to be seen in India as late as 1793 and strawberry and breadfruit in 1798 (Singh, 1979).

In the 19th century, European settlers and missionaries introduced several fruits and helped in establishing commercial orchards in this country. During the British period fruit culture started developing a little faster because of improved irrigation measures, transport and other facilities. The temperate fruits in the hills and the citrus fruits, e.g., Malta and several varieties of grapefruit in the plains were introduced and their culture developed in North India.

1.2 Development in the Present Century

Prior to the establishment of Indian Council of Agricultural Research, the development work of fruit was the responsibility of the States. There was no organised work in this field and also not much efforts were made to solve various problems of orchards. With the establishment of ICAR in the year 1929, the organised work in the development of orcharding could be taken up. A good deal of work could be carried out on regional problems of fruit growing during the period from 1929 to 1954 and a number of research stations could be established in different States with the help of ICAR. The research work on fruits could be organised on regional basis during the Second Five-Year Plan and this led to the opening of 8 Regional Fruit Research Stations in different regions. These stations were Mashobra (Himachal Pradesh), Abohar (Punjab), Kahikuchi (Assam), Pune (Maharashtra), Kodur (Andhra Pradesh), Chethali (Karnataka), Saharanpur (Uttar Pradesh) and Sabour (Bihar). There were other coordinated schemes run by the ICAR to solve certain specific problems, e.g., 'die-back' scheme on citrus, hormone application in horticulture, improvement in date-palm and banana cultivation, etc.

The Regional Fruit Research Stations were handed over to their respective States during the Third Five-Year Plan. The Indian Institute of Horticultural Research was established during the Third Five-Year Plan. It is engaged in conducting research work on fruits, vegetables and flowers. During the Fourth-Five-Year Plan, All India Coordinated Fruit Improvement Project was initiated so as to solve different problems of fruit industry with two main centres—one at Hessarghatta, Bangalore and other at IARI, New Delhi. Later on, different regional stations were established in different climatic regions under this scheme. The research work on mango, papaya, grape, citrus, banana, pineapple, etc., is specially being carried out under this project. Viewing the national significance of mango, the Central Mango Research Station at Lucknow, (Uttar Pradesh) was established in the year 1972.

1.3 Brief Achievements

There has been some advancement in the sphere of horticultural research during the recent years. Some of the advances made in the research on tropical and subtropical fruits in India are as under :

Intensive work undertaken at New Delhi and Punjab resulted in important varieties of grape like Pusa Seedless and Perlette (Mukherjee and Majumdar, 1966). Among guavas, 'Lucknow-49' is one of the best (Cheema and Deshmukh, 1927) and in papaya improved varieties are 'Co. 1' and Coorg Honey Dew (selected

from Honey Dew), which gives practically no male plants (Aiyappa and Nanjappa, 1959). A good deal of work on papaya breeding has been conducted at IARI Regional Station, Pusa, Bihar which has led to the production of some promising strains like Pusa Delicious, Pusa Majestic, Pusa Dwarf and Pusa Giant (Ram, 1982). Pusa Delicious and Pusa Majestic are gynodioecious, and produce cent per cent fruiting plants. The self-incompatibility mechanism observed in Langra, Dashehari and Chausa at Delhi (Singh *et al*, 1962) would help in making large number of crosses without emasculating the anthers. Arkawati, Arka Kanchan, Arka Shyam and Arka Hans varieties of grape and Ganesh pomegranate have also been evolved. In mango Mallika and Amrapali have been released from IARI, New Delhi.

The stooling in mango (Mukherjee and Majumdar, 1964) and guava (Majumdar and Mukherjee, 1968) has been recommended for clonal propagation. Mango and guava orchards can now be multiplied by veneer grafting, cutting and stooling (Mukherjee 1973). The work on the propagation of tropical and subtropical fruit plants has been reviewed by Mukherjee and Majumdar (1973). There is tremendous scope for top working in mango, ber (*Zizyphus mauritiana*), guava, custard apple, aonla, bael, etc. It has been observed that while propagating aonla, the scion bud should always be taken from branches which are known for good fruiting, otherwise the resulting plant will bear only male flowers and hence unproductive. Mist propagation technique has been found to induce rooting in many difficult-to-root fruit plants like mango, guava and litchi. The use of IBA and other treatments have further improved the success of cuttings under mist (Basu *et al*, 1966; Sen, *et al*, 1970).

Ultra-high density systems have been developed in pineapple and banana at IIHR, Bangalore. It is possible to have a high density of 63,758 plants per hectare as against 15,000-20,000 plants hectare in pineapple (Chadha, 1981). In North Bengal, plant population of 64,000 per hactare has yielded 94·5 tonnes fruit (Bose *et al*, in press). Treatment of calcium carbide for round the year harvest of fruits has been standardised to ensure supply and better price for the fruits (Sen *et al*, 1980 and Bose *et al*, in press). It has also been demonstrated that in Robusta banana the yield as high as 174 tonnes can be obtained by planting at a spacing of 1·2 m × 1·2 m instead of 2·0 m × 2·0 m and by following improved practices. In mango, the Amrapali plants up to 1,600 per hectare can be accommodated as against 100 plants in usual mango orchards.

Root distribution pattern in mango, guava and grapes by tracer technique was carried out at IARI, New Delhi as summarised by Singh (1973). Nutrient status of some fruit trees has also been assessed. The work on the certain aspects of agro-techniques of citrus, banana, mango, guava, grape, phalsa, pineapple, papaya, etc., has been published. Research carried out on drip-irrigation for banana and papaya at Coimbatore indicated the saving of nearly 40-70 per cent of the total quantity of water used for conventional irrigation. The use of remote sensing

technique is new development. The technique could be used in the identification of healthy and declining mandarin trees at Gonikopal in Coorg, Karnataka (Chadha, 1981).

A good deal of work has been published on citrus die-back which affects citrus species in India (Aiyappa and Srivastava, 1967 ; Capoor, 1975 ; Rao *et al*, 1975). Emphasis has been laid on the proper up-keep of the orchards. The plants of mandarins and sweet oranges should be propagated from only those plants which are free from viruses. Marked increase in the production of mandarin orange and improvement in fruit quality have been recorded by Bose *et al*, (in press) on 40-55 years' old declined plants by treatment with N, P, K, Zn and Cu. Notable contributions have been made at Kanpur and other places on bearing habits of fruits like aonla, litchi, jamun, mango, guava, loquat, etc., (Singh, 1958, Bajpai and Shukla, 1962 ; Bajpai, 1965 ; Misra and Bajpai, 1973 ; Shukla and Bajpai, 1974 ; Mitra, *et al*, 1981). In the recent past work on the use of hormones on different fruit crops indicated that better yields with good quality fruits can be obtained for example in grapes, phalsa, strawberry, mandarins, sweet oranges, etc. Different chemicals have helped considerably in checking fruit drop in citrus, mango, litchi, grapes, etc. Mann *et al*, (1977) noted zinc deficiency in citrus fruits and it can be controlled by spraying 0·4-0·6 per cent zinc sulphate. Leaf scorch in mango has been found due to chloride toxicity (Pandey *et al*, 1974).

Some encouraging results have been reported in regard to physiology of flowering and fruit growth in mango (Chacko *et al*, 1972 ; Agrawal *et al*, 1980 ; Chattopadhyaya *et al*, 1980 ; Kumar, 1982) and pineapple (Das Biswas *et al*, 1982). The physiological and biochemical studies have been conducted in a number of fruits, e.g., mango, banana, litchi, grapes, date and maturity standards have also been fixed up under some agro-climatic conditions. Studies conducted at New Delhi (Majumdar *et al*, 1970) and Kanpur (Bajpai and Shukla, 1978) have indicated that application of NAA at 200 ppm during October considerably reduces the extent of mango malformation. Post-harvest studies have been carried out on a number of fruit crops and optimum storage conditions of most fruits have been worked out. Some package and practices of growing important fruit crops under Indian conditions have been described (Singh *et al*, 1967 ; Singh, 1979 ; Singh, 1981) which would prove valuable to the fruit growers.

1.4 Tropical and Subtropical Fruits and their Importance

Tropical fruits require hot and humid summer and mild winter. Fruits, like mango, banana, cashew, sapota, pineapple, papaya, mangosteen, breadfruit, etc., fall into this group. Subtropical fruits are grown in subtropics or intermediate zones between the true tropics and temperate region. These fruits require climate

comparatively dry and hot and the winter relatively less cold. The orange, grapefruit, lime, lemon, litchi, grape, date, fig, guava, avocado, and pomegranates are some typical examples of subtropical fruits. However, no definite demarcation can be made between climatic requirement of tropical and subtropical fruits as tropical fruits like mango, banana, jackfruits, etc., are also grown in commercial scale in subtropical region. On the slopes of submontane region and in subtropical plains some varieties of plum (Sharma and Singh, 1975) and peach can grow successfully.

Cultivation of these fruits contributes to the health, happiness and prosperity of the people. It is often stated that the standard of living of the people can be judged by the production and consumption of fruit per capita. The preservation industry, the wine industry, the cashew nut and the coconut-oil industries depend on such horticultural raw materials.

A number of fruit crops occupy an important place in international trade. Above all fruits are protective foods necessary for the maintenance of human health. They also contribute to the aesthetic side of rural and homelife of the community. Fruits have their own medicinal significance and we are also familiar with their religious importance.

Nutritive value of fruit

Importance of fruits in human diet is well recognised. Our diet is very poor and lacks in essential contents like vitamins and minerals. As compared to many developed countries, and even some developing countries, our per capita per day consumption of fruits is one of the lowest (46 gm), being much below the minimum dietary requirement i.e., 85 gm (Chadha, 1981). The fruits are the chief source of vitamins which help in the maintenance of proper health and resistance to diseases. They also provide minerals like calcium, iron, etc., the deficiencies of which may lead to disturbances in the metabolism and can cause several ailments. Fruits are also rich in pectin and cellulose which stimulate intestinal activity and save us from various disorders. Fruits like banana and dates are rich source of energy giving carbohydrates. Fruits provide higher energy value per unit area as compared to cereals like wheat (Table 1). The deficiency symptoms of important vitamins and their availability in tropical and subtropical fruits are given in Table 2.

Fruits are also good source of minerals like calcium, magnesium, phosphorus, potassium, iron, sulphur, copper, etc., which are found in sufficient amounts. Karonda, cashew nut, avocado, bael, raisins, dates, lemon, mosambi, etc., are good sources of minerals. Among these, karonda is the richest source of iron followed by dates. The mango and guava also supply fair amount of iron. Litchi, cashew nut and wood apple contain good amount of calcium and phosphorus. Fruits also supply carbohydrates, proteins, and fats. Proteins and fats are found in very small quantities in fresh fruits. Nuts are very good source of these

TABLE 1. COMPARATIVE ENERGY VALUE PRODUCED BY ONE HECTARE OF WHEAT AND SOME FRUIT CROPS

Crop	Calorific Value per 100 g [a]	Edible Portion (%) [b]	Average Yield/ha	Average Edible Yield/ha	Energy Value/ha Calorific Value (Kcal)	Kilojoules (KJ)
	b		c			
Wheat	341	100	16·49 quintals	16·49 quintals	5,623,090	23,616,978
			d			
Banana	153	71	17·8 tonnes	12·63 tonnes	19,336,140	81,211,788
			e			
Date palm	283	86	9·2 tonnes	7·91 tonnes	22,390,960	94,042,032
			f			
Papaya	40	75	50·0 tonnes	37·50 tonnes	15,000,000	63,000,000
			d			
Guava	66	100	8.7 tonnes	8·71 tonnes	5,748,600	24,144,120

a. Values based on analysis from Nutrition Research Institute, Coonoor as recorded in "Fruit Culture in India," ICAR, Publication, 1967

b. According to Gopalan *et al*, (1971)

c. Average India (1980-81), *Source*—FAO Production Year Book Vol. 35, FAO, RQME (cf. Fertiliser Statistics 1981-82, The Fertiliser Association of India)

d. Average India (1981-82), *Source*—Misra (1982)

e. *Source*—Singh *et al*, (1967)

f. *Source*—Ram (1982) ***Phal Phool***, April-June issue

constituents. The cashew nut contains 22·3 per cent carbohydrates, 21·2 per cent protein, and 46·9 per cent fat. Banana can give 36·4 per cent carbohydrates. dates (Persian) 67·3 per cent, karonda (dry) 67·1 per cent, bael 30·6 per cent and raisins 77·3 per cent. Besides, cashew nut, wood apple, dates, raisins, mangosteens are good sources of protein. A number of amino acids have been observed in several fruits.

Fruits are also rich sources of organic acids which stimulate appetite and help in proper digestion. Citric acid is found abundantly in citrus fruits, while tartaric acid in grapes. Papaya also contains a protein digesting enzyme; which resembles pepsin. Fruits also provide bulk of roughage due to high cellulose content, which prevents constipation. Detailed nutritive value of fruits is given in Table 3.

TABLE 2. THE DEFICIENCY SYMPTOMS OF IMPORTANT VITAMINS IN HUMAN BODY AND THEIR AVAILABILITY IN TROPICAL AND SUBTROPICAL FRUITS

S. No.	Name of Vitamin	Major Deficiency Symptoms	Availability mg/100 g
1.	A (found as carotene)	Night blindness, improper growth of bones, susceptibility to diseases, retardation of growth in young age.	*Mango (4800), Papaya (2020), Dates (600), Jackfruit (540), Orange (350)
2.	B_1 or Thiamine	Beri-beri, paralysis, loss of sensitivity of skin, enlargement of throat, loss in weight and fall of body temperature	Cashew nut (630) Banana (150) Grapefruit (120)
3.	B_2 or Riboflavin	Loss of weight, lack of appetite, sore throat, cataract, swollen nose, redness of the eye, soreness of the tongue, scaliness of the skin, scrotal dermatitis.	Bael (1191) Papaya (250) Cashew nut (190) Litchi (122·5) Pineapple (120) Wood apple (170) Pomegranate (100)
4.	Nicotinic acid or Niacin	Pellagra	Cashew nut (2·1), Dates Persian (0·8) Bael (0·9)
5.	Ascorbic acid or Vitamin C	Scurvy, disorder of skin, tooth decay	Aonla (600-700), Guava (299), Orange (68), Lime (63), Pineapple (63), Lemon (39)

* Vitamin A in international unit

Medicinal value

Different fruits like mango, guava, banana, bael, jamun, papaya, and aonla are quite nutritive and possess very good medicinal value. Fruits and fruit juices are essential for good growth of children. Some fruits are very useful in treating a number of ailments like scurvy, night blindness, asthma, bronchitis, fever, anaemia, stomach troubles, ulcers, etc. Some fruits are rich in pectin which stimulates intestinal activity. Use of bael and papaya is often recommended for curing stomach troubles. Patients are given mosambi juice for getting energy and quick relief. Besides fruits, other portions of fruit plants, e.g., bark, leaves, roots, etc., are used for preparing medicines. *Triphala*, is an Ayurvedic combination of harre

TABLE 3. NUTRITIVE VALUE OF SOME IMPORTANT

Name of the Fruit	Moisture per cent	Protein per cent	Fat (Ether Extractive) per cent	Mineral Matter per cent	Fibre per cent	Carbo-hydrate per cent
1	2	3	4	5	6	7
Aonla	81·2	0·5	0·1	0·7	3·4	14·1
Avocado	73·6	1·7	22·8	1·1	—	0·8
Banana	61·4	1·3	0·2	0·7	—	36·4
Bael	64·2	1·3	0·2	1·5	2·2	30·6
Ber (Zizyphus)	85·9	0·8	0·1	0·4	—	12·8
Breadfruit	79·5	1·5	0·2	0·9	..	17·9
Cashew nut	5·9	21·2	46·9	2·4	1·3	22·3
Custard apple	73·5	1·6	0·3	0·7	..	23·9
Dates (Persian)	26·1	3·0	0·2	1·3	2·1	67·3
Fig	80·8	1·3	0·2	0·6	-	17·1
Grape (Blue)	85·5	0·8	0·1	0·4	3·0	10·2
Grapefruit (Marsh Seedless)	85·5	1·0	0·1	0·4	—	10·0
Guava (Plains)	76·1	1·5	0·2	0·8	6·9	14·5
Guava (Hills)	85·3	0·1	0·2	0·6	4·8	8·1
Jackfruit	77·2	1·9	0·1	0·8	1·1	18·9
Jamun	28·2	0·7	0·1	0·4	0·9	19·7
Karonda (Dry)	18·2	2·3	9·6	2·8	—	67·1
Lemon	85·0	1·0	*0·9	0·3	1·7	11·1
Lime	84·6	1·5	1·0	0·7	1·3	10·9
Litchi	84·3	0·7	0·3	0·7	2·25	9·4
Loquat	87·4	0·7	0·3	0·5	0·9	10·2
Mango (Green)	90·0	0·7	0·1	0·4	- -	8·8
Mango (Ripe)	86·1	0·6	0·1	0·3	1·1	11·8
Mangosteen	84·9	0·5	0·1	0·2	—	14·3
Orange	87·8	0·9	0·3	0·4	—	10·6
Papaya	89·6	0·5	0·1	0·4	–	9·5
Pineapple	86·5	0·6	γ0·1	0·5	0·3	12·0
Pomegranate	78·0	1·6	γ0·1	0·7	5·1	14·6
Pumelo	88·0	0·6	γ0·1	0·5	0·6	10·2
Raisins (Dried grapes)	18·5	2·0	0·2	2·0	--	77·3
Wood apple	69·5	7·3	0·6	1·9	5·2	15·5

Source: Values Based on Analysis from Nutrition Research Institute, Conoor as Recorded in

Calcium per cent	Phosphorus per cent	Iron per cent	Colorific Value per 100g	Carotene (Intern. Vit. A Units per 100g)	Vitamin B_1 (mg per 100g)	Nicotinic Acid mg per 100g	Ribo-flavin mg per 100g	Vitamin C mg per 100g
8	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
0·05	0·02	1·2	59	—	30	0·2	—	600
0·01	0·08	0·7	215	—	—	—	—	13
γ 0·01	0·05	0·4	153	Trace	150	0·3	30	1
0·09	0·05	0·3	129	186	12	0·9	1191	15
0·03	0·03	0·8	55	70	—	—	—	—
0·04	0·03	0·5	79	15	—	—	—	—
0·05	0·45	5·0	596	100	630	2·1	190	—
0·02	0·04	1·0	105	Trace	—	—	—	—
0·07	0·08	10·6	283	600	90	0·8	30	Trace
0·06	0·03	1·2	75	270	—	0·6	50	2
0·03	0·02	0·4	45	15	40	0·3	10	3
0·03	0·03	0·2	45	—	120	0·3	20	31
0·01	0·04	1·0	66	Trace	30	0·2	30	299
0·05	0·02	1·2	38	Trace	—	0·3	—	16
0·02	0·03	0·5	84	540	30	0·4	—	—
0·02	0·01	1·0	83	—	—	—	—	—
0·16	0·06	39·1	364	—	—	—	—	—
0·07	0·01	2·3	57	Trace	20 (Juice)	0·1 (Juice)	4	39 (Juice)
0·09	0·02	0·3	59	26	20 (Juice)	0·1 (Juice)	—	63
0·21	0·31	0·03	42	14	87·5	—	122·5	Trace
0·03	0·02	0·7	46	—	—	—	—	—
0·01	0·02	4·5	39	150	—	—	30	3
0·01	0·02	0·3	50	4800	40	0·3	50	13
0·01	0·02	0·2	60	—	—	—	—	—
0·05	0·02	0·1	49	350	120	0·3 (Juice)	60	68
0·01	0·01	0·4	40	2020	40	0·2	250	46
0·02	0·01	0·9	50	60	—	—	120	63
0·01	0·07	0·3	65	—	—	—	100	16
0·03	0·03	0·1	45	200	30	0·2	—	20
0·10	0·08	4·0	319	—	60	0·5	—	Trace
0·13	0·11	0·6	97	—	—	—	170	—

Fruit Culture in India, ICAR Publication, 1967.

(*Terminalia chebula*), bahera (*Terminalia belerica*) and aonla (*Emblica officinalis*). The *Chavanprash*, a health tonic is also prepared with aonla fruits. On account of the various qualities that fruits possess, they are classified as protective foods, which supplement the human diet from various angles.

1.5 Fruits Culture as an Economic Proposition

(i) The well established and maintained orchards can offer better yields per unit area and returns as compared to field crops from the same piece of land. During the non-bearing stage of orchards, intercrops like vegetables and pulses and fillers like papaya and phalsa, can be grown to compensate the expenses involved in establishing an orchard. Singh (1979) states that a gross income of Rs 62,500/hectare can be obtained from a good vineyard. High yields and returns can be achieved from banana, mango, aonla, papaya, etc. Papain extracted from unripe papaya fruits can fetch Rs 40,000–50,000 per hectare with an additional income of Rs 20,000 per hectare from selling of scarred fruits. The aonla orchards can provide a handsome income of Rs 20,000 per hectare.

(ii) A fruit grower remains engaged for the whole year and there is an opportunity for maintaining labourers throughout the year unlike the cereals where one cannot keep himself and employ the labourers during the slack span.

(iii) Some fruits can offer best utilisation of waste lands, arid, and semi-arid regions for getting higher income with minimum inputs. Crops like ber, bael, aonla, custard apple, phalsa, wood apple, karonda, lasora, imli, breadfruit can be grown in such areas. In villages where such lands are available, lot of the villagers can be improved by encouraging them to grow these crops. This will go a long way in enhancing the wealth and prosperity of the farmers.

(iv) Some fruit plants grown in the backyard of the house particularly the short duration ones and others too in 'nutrition fruit garden', will help not only in providing balanced diet but also curtail extra expenses on these items.

(v) Fruits earn handsome foreign exchange. Fresh as well as preserved products have better foreign market. There is immense scope of increasing export of fruits and their products.

Industrial application

The fruit-growing provides raw materials to several ancillary industries like preservation, dehydration, essential oils, package, transport, refrigeration, cashew nut, coconut-oil industries and wine industries, etc. These industries provide employment to large number of people. Mulberry plants are associated with silk industry. Bee-keeping in the orchards provides honey. Starch can be obtained

from mango kernels and can be used in textile, jute, paper indutries, etc. Raisins are prepared from grapes and papain obtained from unripe papaya is used in tanning industry, in the clarification of beer, and in the manufacture of chewing-gum. Fibres and flour of banana are not uncommon. Besides, a number of fruit plants provide wood for making various furniture, well-rings, doors, hockey sticks, bats, etc. Several fruit products as well as by-products have, their own significance in both internal and external trade.

Aesthetic consideration

Fruit plants add to the aesthetic beauty of the environment, they purify the air and decrease pollution. Who will not admire the beauty of the flowers and ladden fruit branches ? One can enjoy the smell and beauty of the blossoms (citrus, peaches, loquat, mango, etc.) which appear quite soothing to the eyes.

Religious significance

As stated earlier fruits, flowers, leaves and other parts have religious importance and as such these have been used in worships, religious occasions, marriages, etc., in one or the other forms. Bael leaves and green fruits are offered to Lord Shiva and dried mango twigs are used in *Hawan*. References to these can be easily traced in various religious testaments.

Miscellaneous importance

Seedling fruit plants, e.g., mango (*Mangifera indica*) jamun (*Syzygum cuminii*), mahua (*Madhuca latifolia*), imli (*Tamarindus indica*), etc., growing along the highways, roads and the like form a good roadside avenues. Fruit trees affect the rain and drought and they bring improvement of soil and help in checking the soil erosion. Variety and varied degree in taste, flavour and aroma are available from fruits. Fruits are available almost throughout the year.

1.6 Present Status

Area and production

The fruitwise as well as Statewise data regarding area, production and productivity are presented in Table 4. At present the area under fruit in India is estimated to be about 2·5 million hectares with a production of about 22·2 million tonnes (1981-82). Chadha (1981) reported 2·3 million hectares area under fruit during 1979-80 with a total production of 20·8 million tonnes of which mango accounted 8·4, banana 5·3 and citrus 1·7 million tonnes. The production figures for mango, banana, citrus and guava were about 8·7, 5·6, 1·8 and 1·3 million tonnes respectively during 1981-82 (Misra, 1982).

Statewise figures (Table 5) indicate that Uttar Pradesh accounts 5·943 lakh hectares which comes to about 24 per cent of the total area under fruits (1981-82). Uttar Pradesh produces about 15 per cent of the total fruit production, followed by Tamil Nadu, Bihar, Andhra Pradesh, Karnataka and Kerala. The productivity (Tonnes/hectare) is the highest in Gujarat (22·65), followed by Madhya Pradesh, Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh.

TABLE 4. FRUITWISE AREA, PRODUCTION AND PRODUCTIVITY DURING 1981-82

Area : **Lakh ha**
Production : **Lakh Tonnes**
Productivity : **Tonnes/ha**

S. No.	*Fruits*	*Area*	*Percentage of the Total Area*	*Production*	*Percentage of the Total Productivity*	*Productivity*
1.	Apple	1·537	6·18	9·270	4·18	6·03
2.	Banana	3·120	12·54	55·537	25·05	17·80
3.	Citrus	2·307	9·28	17·591	7·94	7·62
4.	Guava	1·509	6·07	13·148	5·93	8·71
5.	Grapes	0·114	0·46	2·225	1·00	19·46
6.	Pineapple	0·835	3·36	6·431	2·90	7·70
7.	Mango	10·015	40·27	86·628	39·08	8·65
8.	Other fruits	5·433	21·84	30·859	13·92	5·68
	Total	24·870	100·00	221·689	100·00	8·91

Source—Misra (1982)

It is estimated that the area under fruit crops would be 2·9 million hectares and the fruit production 25 million tonnes by 1984-85. The National Commission on Agriculture has projected the area under fruit crops to be 4 million hectares by 2000 AD at the present rate of expansion.

Export and import

Fruit can earn very handsome foreign exchange. However, India's share is rather insignificant in the international fruit trade. During 1979-80, the export of fresh fruits was of the order of 17,696 tonnes and that of processed fruits like mango juice and canned and bottled fruits, 10,000 tonnes. The net foreign exchange earned was Rs 17 crores. There was a decline in the export earnings (14·44 crores) from fruits and fruit products during 1980-81. A quantity of 7241

tonnes of fresh fruits could only be exported during 1980-81 (Chadha, 1981 ; Misra, 1982). Fresh and processed products of mango form the major part of the fruit trade. We also export banana, citrus fruits (oranges, mandarins, grapefruits, lemon, limes), pomegranates, cashew nut, guava, dates, raisins, grapes, coconuts, sapota, ctc. Although India produces considerable amount of banana

TABLE 5. STATEWISE AREA AND PRODUCTION OF FRUITS IN INDIA DURING 1981-82

Name of the State	Area (Lakh ha)	Percentage of the Total	Production (Lakh tonnes)	Percentage of the Total Production	Productivity Tonnes/ha
All India	24·870	100	221·689	100·0	8·91
1. Uttar Pradesh	5·943	23·89	32·968	14·87	5·54
2. Assam	2·542	10·22	8·781	3·96	3·45
3. Bihar	2·038	8·19	22·290	10·05	10·89
4. Kerala	1·883	7·57	16·903	7·63	8·97
5. Andhra Pradesh	1·702	6·85	22·153	9·99	13·01
6. Tamil Nadu	1·493	6·00	25·192	11·37	16·87
7. Orissa	1·443	5·80	12·407	5·60	8·59
8. Karnataka	1·341	5·39	20·262	9·15	15·11
9. Jammu & Kashmir	1·132	4·55	5·200	2·34	4·59
10. West Bengal	1·017	4·09	8·901	4·01	8·75
11. Maharashtra	0·982	3·95	13·853	6·24	14·10
12. Himachal Pradesh	0·972	3·91	3·705	1·67	3·81
13. Gujarat	0·456	1·83	10·331	4·66	22·65
14. Madhya Pradesh	0·444	1·78	8·628	3·89	19·43
15. Punjab	0·303	1·22	1·482	0·66	4·89
16. Tripura	0·275	1·10	2·655	1·20	9·65
17. Others	0·904	3·63	5·978	2·69	6·61

Source—Misra (1982)

citrus, etc., but compared to world production, its share is negligible in the international trade of the. crops. The export quantities of fruit products—mango juice and other canned / bottled fruits increased from 9993·0 tonnes in 1979-80 valued at 6·6 crores to 13916·0 tonnes in 1980-81 worth Rs 9·66 crores (Misra, 1982). There has been decline in the export of cashew kernels from 37848·0 tonnes in 1979-80 to 30951·0 tonnes during 1980-81 (Table 6). There exists immense potentialities for banana export, but looking into the complexities involved in its production, processing, packaging, transport and marketing competition in

international market, a concerted effort will have to be made for boosting its export. India has been exporting mainly to the European countries but there exists a good scope of increasing our export of fruits to the oil-rich Middle-East countries (Chadha, 1981). Data on export of fruits and fruit products have been summarised in Tables 6 and 7.

TABLE 6. EXPORT OF FRUITS AND THEIR PRODUCTS FROM INDIA

S.No.	Particulars	1979-80		1980-81	
		Quantity (Tonnes)	Value (Rs in Lakhs)	Quantity (Tonnes)	Value (Rs in Lakhs)
1.	Fruit (Fresh)				
	(i) Mango	4294·00	468·00	4174·00	439·00
	(ii) Other fruits	13402·00	580·00	3067·00	202·00
2.	Cashew kernel	37848·00	11791·00	30951·00	13183·41 (up to Feb. 81)
3.	Fruit products				
	(i) Mango juices	5728·00	372·00	6299·00	354·00
	(ii) Other canned/ bottled fruit	4265·00	288·00	7617·00	612·00
	(iii) Pickles/chatney	10517·00	728.00	6090·00	478·00

Source—Misra (1982)

TABLE 7. TOTAL EXPORT AND REEXPORT OF FRUITS FROM INDIA

Particulars	Export (000 Rs) April to March			Reexport (000 Rs) April to March		
	1975-76	1976-77	1978-79	1979-80	1976-77	1979-80
Fruits fresh and nuts (not including oil nuts), fresh or dried	102,44,17	115,15.05	102.73,89	145.28.90		2,82
Dried fruits, including artificially dehydrated	82,72	81,73	--	—	12	
Fruit preserved and fruit preparations	5.11.11	9,16.49	10,25,99	8.56.51	1	

Source—Monthly Statistics of Foreign Trade of India

Imports data for fruits are given in Tables 8 and 9. It may be clearly observed that the import of fruits and fruit product decreased during these years (Table 8). We are importing from Nepal, Kenya, Afghanistan, UK., etc. We imported 4167 tonnes of cashew nuts worth Rs 2·3 crores from Kenya during 1980-81 for processing as they do not have processing factories. Grapes and pomegranates are

being imported from Afghanistan. The Government has decided to canalise import of fresh fruits from Afghanistan through National Agricultural Cooperative Marketing Federation of India Limited (NAFED). Under this scheme the importers who desire to import fresh fruits can register themselves with NAFED. India can have a good market for its fruits in Mauritius. At present Mauritius is importing fruits mainly from the European countries, Australia, New Zealand, and South Africa at very high price. She is interested in importing apple, citrus, grapes, mangoes, in considerable quantities from India (Anonymous, 1982).

TABLE 8. TOTAL IMPORT OF FRUITS

Particulars	Imports (000 Rs) April to March		
	1978-79	1979-80	1980-81
Fruits fresh and nuts (not including oil nuts) fresh or dried	50,92,08	41.75,43	10.98.29
Fruit preserved and fruit preparations	4.14	32	26

Source - Monthly Statistics of Foreign Trade of India

TABLE 9. IMPORTS OF IMPORTANT FRUIT CROPS

Particulars	April 1980	March 1981
	Values (Rs)	Weight
Lemon and lime (Nepal)	2300·00	1000 kg
Banana fresh dried (Nepal)	9000·00	750 kg
Cashew nut (Kenya)	23347251·00	4167 tonnes
Mango fresh (Nepal)	35750·00	21450 kg
Pomegranates (Afghanistan)	762691·00	225365 kg
Jam, jelly, marmalade, puree and paste of other fruits (Nepal)	8000·00	16793 kg
Other prepared preserved fruit and other fruit squash (UK)	18776·00	100 kg

Source—Monthly Statistics of Foreign Trade of India

For boosting the export of fruits and fruit products, it is desirable that we should concentrate our efforts to increase the production of fruits, otherwise the prices of these fruits would increase in the domestic market. Increased production of certain fruits would also help in minimising the imports.

1.7 Scope of Tropical and Subtropical Fruits

There is tremendous scope of developing fruit industry in our country. With the renewed research and development strategy, it can be expected that the tropical and subtropical fruits would play a greater role in future in meeting the consumption requirements of the people and catering to a number of international markets. During the recent past there have been some advancements in the field of research and development of fruit crops but the transfer of technology to the growers has not been satisfactory. There is urgency to provide greater intensive extension support and technical know-how to the growers on nutritional needs of fruit trees. proper cultural schedules for pruning, training, interculture, plant protection measures against insect-pests and diseases, etc.

The productivity (tonnes/ha) of most fruits in India is quite low at present against the higher productivity in foreign countries. For example average yield per hectare in citrus works out to be 7·62 tonnes in India as compared to 17–30 tonnes per hectare in Spain, Italy and Japan. The average pineapple yield is 7·70 tonnes per hectare (Misra, 1982) as against 60–70 tonnes in countries like Hawai, Philippines and Ivory Coast (Mirdha, 1973). The mango covering 40·27 per cent of the total area under fruits and accounting 39·08 per cent of the total fruit production, the national average is only 8·65 tonnes per hectare (Table 4). These figures clearly reveal the necessity of boosting the productivity of fruit crops. The smaller size of Indian orchards and poor orchard efficiency are the major factors responsible for lower productivity. Chadha (1981) outlined the major problems faced by fruit industry and ways and means to develop it on sound footing. The productivity can be increased by use of improved varieties, better planting material, high density orchards and by employing improved and standardised agro-techniques in various fruit crops. There is also urgency to find definite solution against various disorders like irregular bearing, malformation and spongy tissue in mango, citrus decline, guava wilt, papaya mosaic, Panama wilt and leaf spot in banana, as all these adversely affect the production of these crops.

Nutritional requirements for different fruit crops need to be standardised for non-bearing as well as bearing stages in different soil and climatic conditions and the schedules obtained should be demonstrated and made known to the orchardists. In this context soil as well as leaf analysis service will have to be made available. We have to develop leaf nutrient guides on well laid out nutritional trials in different regions. This should be done at least in some important fruit crops like mango, banana, citrus, grape, guava, etc. There is need to work out fertiliser use efficiency in fruit crops as it is lacking in most fruit crops. The fertiliser placement and root activity studies using stable and radioactive isotopes are required to be made in fruit crops. It will largely help in understanding the time, method and

right type of fertiliser application. It will also provide better knowledge of problems associated with irrigation practices and plant population density.

Mr. W. D. Hopper, Vice-President of the World Bank, In-charge of South Asia, as quoted by Mukherjee (1982) observes that in the populous countries like China and India where the potential for expanding area is becoming almost exhausted, the increase in yield will have to come from the change in internal architecture of the plant through new science of biotechnology, or the genetic engineering. The usual way of changing genetic characteristics has been through grafting and crossing to have desirable features such as higher yield potential, resistance to adverse conditions like drought or soil salinity or more protection againgt disease. The biotechnology offers it by way of fusing plant cells through chemical means. Such a fusion that has been achieved is between sunflower plant and frenchbean to produce 'sunbean'. However, this work is at very early stage. The biotechnology, it is hoped, will have a good scope in modern fruit production.

Rootstock breeding is another aspect which did not receive proper attention in the past. There is need to evolve grape varieties resistant to downy mildew and anthracnose, multipurpose varieties suitable for table, raisin and vine ; guava rootstocks resistant to wilt; papaya resistant to mosaic ; litchi resistant to cracking ; banana resistant to bunchy top and Panama disease, etc. It is also essential to undertake research work for finding suitable rootstocks to extend the fruit growing into arid, saline and other untapped areas.

There are many hardy fruit crops like aonla (*Embilica officinalis*), ber (*Zizyphus mauritiana*), pomegranate (*Punica granatum*), custard apple (*Annona squamosa*), jamun (*Syzygium cuminii*), fig (*Ficus carica*), date (*Phoenix dactylifera*) bael (*Aegle marmelos*), kamrakh (*Averrhoa carambola*), lasora (*Cordia mixa*), barhal (*Artocarpus lakoocha*), phalsa (*Grewia subinaequalis*), wood apple (*Limonia acidissima*), etc., which can be grown in arid and semi-arid regions. The arid and semi-arid regions account for about 70 per cent of the total cropped area and so there is immense scope of increasing the area under these crops in future. The salt tolerance of these fruit crops as well as their agro-techniques need to be assessed in diffenent regions. In Haryana, where a few years back no Dashehari mango plant could be seen, now the orchards of Dashehari have been planted as a part of the Haryana Government's package programme. The area from Kalka to Kalesar is full of Dashehari mangoes (Anonymous, 1983). The Haryana Government has also launched a scheme to popularise the cultivation of ber in the arid zone of south-western area. The growers are opting to the cultivation of mango, chiku, and litchi on the Shiwalik land reclaimed under the development scheme.

The use of remote sensing technique will play a greater role in modern fruit-growing. There is also a good scope in using rhizobium and mycorrhiza for recycling and promoting the utilisation efficiency of nutrients. A good deal of area is under seedling orchards of unknown pedigree which produces fruits of poor quality. There is tremendous scope for top working in mango, ber, guava,

custard apple, aonla, bael, etc. There is need to develop high density orchards. In this context, we have to find out dwarfing rootstocks for mango, guava, sapota, and other fruit trees. The dwarf varieties of papaya, coconuts, banana, etc., have special role to play in increasing the production. The improved agro-techniques for high density orchards of fruits will have to be developed. The other methods which may dwarfen the plants are the use of chemicals like B-9, chlormequat, etc., and pruning and training techniques. To save people from health hazards, the intensive laboratory tests are required on residual toxicity of various chemicals used, e.g., insecticides, fungicides and weedicides.

Recent advances in plant propagation, e.g., tissue culture, mist-technique, use of chemicals, etc., will largely help in rapid multiplication of fruit plants. The clonal propagation of many fruit crops like strawberry, banana, pineapple, grapes, citrus, date, etc., would be possible *in vitro*. It will help in producing uniform rootstocks. Dr. Brent Tisserat, the United States Agricultural Research Service Scientist, perfected the cloning of date-palms from tissue culture. It is possible to create copies of hardy survivor plants in test tubes. Tisserat suggests the creation of frozen germ-plasm banks to ensure the availability of the genetic blue prints of all different cultivars for future experimentation. The USDA plant scientists has used liquid nitrogen to freeze date-palm tissue cultures (Anonymous, 1982) and these may be exploited with profit.

Elite progeny orchards-cum-nurseries will have greater role to play and these should be established in different States. In order to maintain clones with genetic purity, multiplication of clones from single plant selection or a hybrid should be strictly followed. The mango and guava rootstocks need to be raised through stooling so as to bring uniformity as seedling stocks show high degree of variation.

More than half of all the fruits produced in America are processed and there has been tremendous increase in the preparation of frozen foods, fruit juices, and baby foods (Tukey, 1957). On the contrary, in our country the processing industry is still in infancy and hence there is a great scope for increasing the area as well as production of the tropical and subtropical fruits so that we can catch up with other advanced countries. We still lack in the production of frozen foods and fruit juices. There is a very good scope for exporting fresh fruits and their products as well to foreign countries. It will help to raise the Indian economy to a great extent.

There is need for problem-oriented research investigation and the research problems have to be tackled from growers' point of view. It is highly desirable that every fruit should pass through a reasonable period of yield testing before it is recommended. Recently a workshop organised by All India Coordinated Fruit Improvement Project of the ICAR, held at Nagpur, recommended the constitution of a committee in the ICAR to prepare the guideline/policy of import and export of planting material of fruit crops and to examine the proposals received

from various places. It would help to a great extent in identifying various problems in fruit production. We have to ensure adequate credit to the growers and also the production programmes have to be supported by trained personnel at all the levels. The small and marginal farmers have been offered assistance from State Bank of India for taking to horticulture as a wholetime vocation at Shiwalik hills in Haryana (Anonymous, 1983). Provision has to be made for proper marketing facilities, packaging, transhipment of fruits for internal as well as external trade, and preservation of fruits both in fresh and canned conditions. There is need to develop cheaper packaging materials for fruits. Cooperatives have to be involved in a big way to safeguard the interests of both the growers and the consumers. There is also need to increase the number of cold storages in our country. All possible post-harvest precautions will have to be taken in handling, marketing and storing of fruits to minimise the post-harvest losses.

Thus, it is apparent that scope of tropical and subtropical fruits in India is quite bright and the production can be greatly increased with the adoption of improved methods of cultivation. It is hoped that the active involvement of the All India Coordinated Fruit Improvement Project of ICAR, Departments of Horticulture of States, Agricultural Universities and the Institutes would prove helpful in solving the major challenges of the fruit industry which will go a long way in boosting the national economy.

More stress should be laid to increase the production per unit area as the land is limited and at the cost of other crops area under fruits cannot be increased. Hence, the scientists have to find out ways and means to increase the production, by evolving high-yielding varieties and methods of better orchard management.

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, view of an orchard

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PLANNING OF ORCHARD

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An orchard, being a capital intensive and long-term venture, deserves careful and well thought-out planning. Fruit trees are perennial, and may be of tropical, subtropical and temperate types, and thus require proper environmental conditions and suitable management practices for their successful growing. Any mistake made initially in planning is likely to put the fruit grower to incur heavy losses throughout the life-span of the orchard. On the other hand, with a carefully prepared plan, the grower is able to provide not only the most economic orchard management, but also for the economic layout and location of roads, drains, irrigation channels, fences, wind breaks, etc. It is, therefore, considered important to plan properly before establishing an orchard. The fruit grower must have full knowledge of the growth and bearing habits of fruit trees including their cultivation requirements for better planning.

2.1 Principles of Orchard Planning

1. The orchard should be established in the right location and site having suitable climatic and soil conditions and other physical facilities required for successful growing of fruits and disposal of the produce.

2. The selected site, if uncultivated, should be cleaned by uprooting the existing trees and bushes and levelled properly after deep tillage. In the hills, the land should be divided into terraces depending on the topography of the land and then levelled within the terraces.

3. Minimum orchard space should be allotted for roads, paths and buildings but in no case it should exceed more than 10 per cent of the total area. Roads and paths should be laid out in such a manner as to occupy the minimum space, but at the same time it should ensure convenience and economy in orchard transport and supervision. The building should be near the road and in the centre of the orchard, if it is a large one (Kunte and Yawalkar, 1955).

4. The drainage and irrigation channels should be kept concealed as far as possible from the visitors and laid out in such a way as to serve the needs of every plot or area in a most efficient and economic manner.

5. As far as possible the orchard should present a nice panoramic view at the main entrance with the background in harmony with it.

6. The evergreen fruits should be planted in the front and the deciduous trees or those shed their leaves partially in some season, at the back.

7. The shorter fruit trees should be located in the foreground, while the taller ones at the rear part of the orchard to facilitate supervision.

8. Fruit trees requiring frequent irrigation should be planted nearer to the source of water, while the rainfed ones be kept farther away.

9. Fruit varieties ripening at a time should be located in adjoining plots to facilitate proper orchard operations.

10. Fruits that attract birds and other animal pests and are prone to be damaged by them should be located close to the watchman's shed.

11. Fertile areas of the orchard should be planted with more paying and gross feeding fruit trees.

12. Self-sterile or self-incompatible fruit trees requiring polleniser should be planted mixed or polleniser varieties be side grafted on the fruit trees themselves to ensure optimum fruit set.

13. The spacing of fruit trees for each species should be the optimum. When intercrops, multiple crops, etc., are to be grown, the spacing of the orchard trees may be kept at its maximum. The vigorous varieties as well as the varieties growing in fertile soil generally require wider spacing.

14. The system of planting of a fruit crop to be adopted in a particular plot should be decided upon much earlier before laying out the orchard.

15. Under dryland horticulture *in situ* method of planting of rootstocks should be followed and later on the desirable scion variety be side grafted when the rootstock attains desirable size.

16. There should be provision for wind breaks around the orchard to protect the fruit trees from the clutches of strong wind.

17. Fencing of orchard sufficiently ahead of planting should be done.

18. Selection of fruit varieties suitable to the area and procurement of genuine plant materials from reliable sources are essential.

19. Nursery for maintaining the clones and raising of seedlings should be located near the water source.

The important points to be considered for planning an orchard are the following :

Selection of site

It is always better to start an orchard in a predominantly fruit-growing area than in a new locality where few or no orchard exists. This will not only help in sharing experience of local fruit growers but also purchasing of plant materials, orchard equipments, transport, marketing, storage of fruits, etc., would be easier through cooperation with other growers (Singh, *et al*, 1963). Besides, the site for an orchard should be either as close to a consuming centre/market as possible or on a metal road or connected by rail. Over and above, the orchard site should have favourable climatic and soil conditions and good source of irrigation.

Climate

The climate of the site where fruits are to be grown on commercial scale must be considered carefully. Factors like day and night temperature, rainfall (frequency, amount and intensity), wind, light, atmospheric humidity, hail storm : frost occurrence, etc., are very important for selection of fruits to be grown there. Listed below are the fruits suitable for regions with different climatic conditions :

Tropical Climate : Fruits like mango, banana, papaya, pineapple, sapota, ber, breadfruit, cashew, coconut, etc., thrive well in this climate.

Subtropical Climate : In this climate, guava, grape, litchi, citrus, date, phalsa, pomegranate, peach (requiring low-chilling), pear, etc., are most suitable.

Temperate Climate : In this climate fruits like apple, pear, peach, plum, blackberry, strawberry, apricot, walnut, almond, etc., grow well.

Hence, while planning the orchard, the fruits suitable to the particular site should be kept in mind and planting of fruit species can be done accordingly taking into consideration the topography also.

Soil

Though most of the fruits may be grown on a wide variety of soils such as clay, sand, sandy loam, clay loam, loam, etc., a loam or sandy loam soil is considered to be the best for most fruits. Shallow soils with rocky substrata, soils with very high or low pH, soils having poor drainage and high water table during rainy season should be avoided (Hayes, 1953).

The fruit growers must have at least a fair knowledge of soil type, its depth, reaction, water table and fertility status before selecting a definite variety of fruit trees to be grown there. The orchard site should have uniform soil with at least three to four feet top soil on which the fruit trees will grow. Sandy soil may be suitably utilised for growing cashew nut, coconut, etc., gravelly red laterite for cashew nut, mango, jackfruit, etc., loamy soil for banana, papaya, litchi, sapota,

etc. However, the orchard soil of poor fertility can be improved in the course of orchard soil management by green manuring, intercropping, etc.

After selecting the site and before planting fruit trees, it is necessary to prepare the land by carrying out certain preliminary operation such as clearing and levelling of land, making provision for irrigation water, providing of fences, planting of windbreaks, planning of buildings, etc.

Clearing and levelling the land

If the land is already under cultivation, nothing except preliminary preparation is necessary. If uncultivated, it is necessary to put them under deep ploughing and levelling. If the selected site is under forest, the existing trees and bushes should be removed by uprooting. The land then should be thoroughly ploughed, harrowed and levelled. While preparing the land, the subsoil which is usually less fertile than the surface soil, should not be disturbed as far as possible. In the hills, terraces should be made along the contours (Dutta, 1966).

Irrigation source

An orchard flourishes well when put under irrigation particularly during the dry months. So the source of irrigation should be a permanent one assuring supply of requisite quantity of irrigation water throughout the year. Whatever may be the source of irrigation—a well, a shallow or a deep tube well—it should be sunk well ahead of planting. In high hills, where the rainfall and snowfall are adequate and evaporation from soil is not very high due to prevailing low temperature, a few tanks may be installed for collection of rain or snow water to tide over the critical periods of the year.

Fencing

To protect the trees of the orchard from frequent visits of wild and stray animals, and to prevent stealing of fruits and other orchard property, some kind of fence is highly necessary. This may be made by erecting mudwalls or high brick walls with tops lined with glass pieces, or barbed wire fencing.

The first one though quite effective against big animals, offer very little obstacle to monkeys and thieves. The second one being permanent and very effective from the security point of view is preferred. But it involves a large initial expenditure which is beyond the means of ordinary fruit growers. The third one, the barbed wire fencing which costs moderately, is not only effective against practically all animals and human beings, but it also neither shades the orchard soil nor takes away any plant food from it.

So, the orchard boundary may be fenced with pillars and barbed wires. The pillars may be of wood, angle iron, stone-cement concrete, etc. This fence may be further strengthened by erecting live hedges which will not only help to stop the

entry of animals and human beings but also form a thick live-wall around the orchard for privacy and help to safeguard the produce which cannot be seen from outside. The live hedge must have the following qualities :

(a) It should be quick growing (b) easy to raise by seeds or cuttings of vegetative parts (c) should be drought resistant (d) should have dense foliage (e) should preferably be thorny (f) should stand pruning to develop thick and compact growth.

The plants suitable for live hedge are *Inga dulcis, Parkinsonia aculeata* L., *Prosopis juliflora, Carissa carandas, Casuarina equisetifolia, Duranta plumeri, Sesbania aegyptiaca, Acacia* sp., *Zizyphus* sp.. *Lawsonia alba, Gliricidia, Bahunia* sp., *Polyalthia longifolia*, etc.

To establish a live hedge, the soil along the fence is dug 2 feet wide and 2 feet deep at the commencement of the rainy season. After sowing the seeds or planting the cuttings along the boundary of the orchard, the plants are allowed to grow. In the course of time trimming and pruning are done to develop a thick and tall hedge as required.

It has also been found very useful when a cattle driven trench of 3 ft. deep and 4 ft. wide is dug after the live hedge around the border.

Windbreaks

Fruit orchards usually face heavy losses when a strong wind of high velocity passes through the orchard. Damages like uprooting of trees, breaking of branches, destruction of blooms, dropping of immature fruits, erosion of surface soil, etc., are caused very often by wind Hence, establishment of a tall-growing windbreak is necessary to protect the orchard.

The planting of windbreaks should precede that of the fruit trees by at least two years, if they are to give effective protection to the orchard. A well-established windbreak reduces the velocity of wind, checks evaporation loss of soil moisture, prevents cold wind and reduces frost damage to a great extent.

The efficiency of a windbreak depends upon the height of the trees and their compactness. Ordinarily it has maximum effectiveness for a distance about 3-4 times as great as its height. The first row of fruit trees should be about 40 ft. away from the windbreak row. To prevent the roots of the windbreak trees from interfering with the normal growth of the fruit trees, a 3-4 ft. deep trench should be dug at a distance of 10 ft. from the windbreak row.

An ideal windbreak should be upright in growth and occupy as little space as possible. It should be tall, mechanically strong, quick growing and sufficiently dense to offer the maximum resistance to the wind. One to two rows of such trees are planted at a close spacing, usually 12-25 ft. apart, for having a tall and close tree-wall which can help to resist the incoming heavy flow of wind. Trees commonly grown as windbreaks are *Polyalthia longifolia, Casurina equisetifolia,*

Erythrina indica, *Eucalyptus globulus*, *Grevillia robusta*, *Dalbergia sissoo*, *Putranjiva roxburghii*, *Syzygium* sp., *Mangifera indica*, *Averrhoa carambola*, *Bambusa* sp., etc.

Buildings

Any building which is to be constructed in the orchard should be planned before planting, though their construction may be done later on. An orchard provides a very pleasant site for a dwelling. Other buildings such as implement shed, bullock shed and labour quarters may also be constructed.

Roads, Paths, Irrigation and Drainage Channels : Planning of roads, paths, irrigation and drainage channels should also be done well in advance. Roads and paths are absolutely necessary for making every portion of the orchard easily approachable and for convenience in operations like manuring, spraying and transportation. The footpaths should be made in between the rows of trees without utilising any additional space of the orchard. Small non-spreading type of avenue trees may be planted beside the road to enhance the beauty of the orchard.

The permanent irrigation and drainage channels should be dug in straight lines and without interfering the main roads to economise the use of irrigation water by avoiding seepage in the channels during the dry and hot seasons and for efficient drainage of excess water from the individual plot of the orchard during rainy season or flood-affected areas.

Before the actual laying out of the orchard and undertaking the planting work, a detailed plan of the orchard (Fig. 1) should be drawn showing the boundary, main gate, roads and paths, source of irrigation, drainage and irrigation channels and also the individual plots for the fruits to be grown. This will help to establish the orchard correctly and conveniently.

Layout

The layout of the orchard is a very important operation. Under this, the arrangement of fruit plants in the plot is carefully done to put the plants at a suitable distance for proper development and for accommodating the requisite number of plants per unit area in addition to improving the aesthetic look of the orchard. Hence, the factors which are considered important for proper layout of the orchard are (i) system of planting and (ii) planting distance of individual fruit species which again would provide the following advantages :

1. Allow equidistance for each tree for uniform growth.
2. Allow easy orchard operations like cultivation, intercropping, irrigation, spraying of plant protection chemicals and growth regulators, harvesting, etc.
3. Proper utilisation of orchard space avoiding wastage of land.
4. Help in proper supervision and management of the orchard.

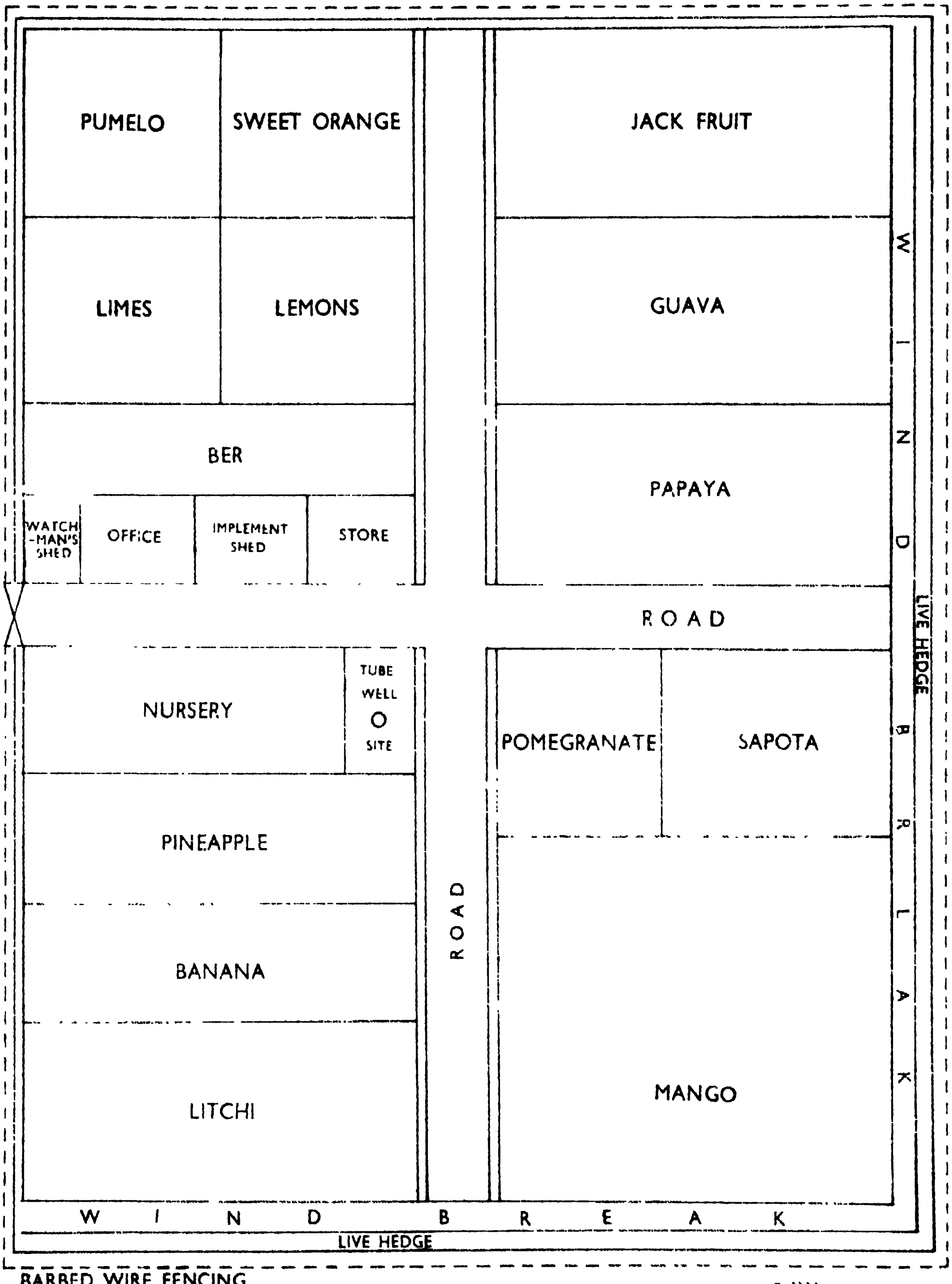
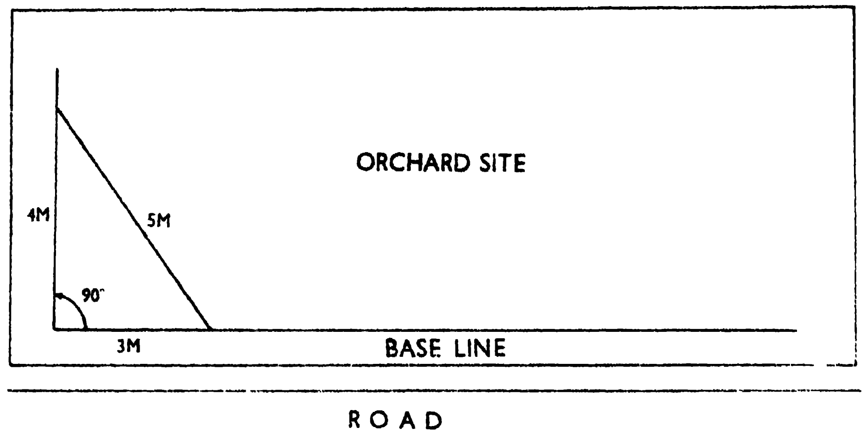


FIG. 1 PLAN OF AN ORCHARD

SYSTEM OF PLANTING



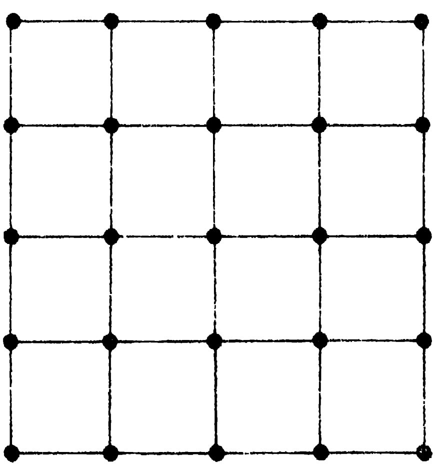


FIG. 2 SQUARE

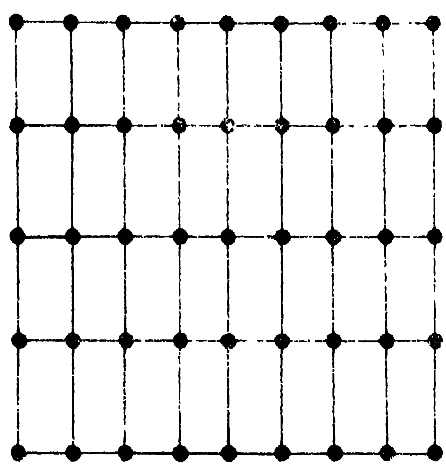


FIG. 3 RECTANGULAR

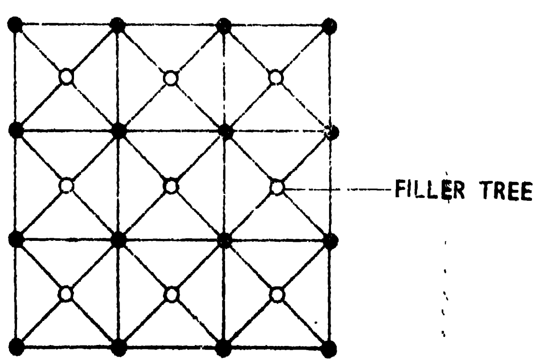


FIG. 4 QUINCUNX

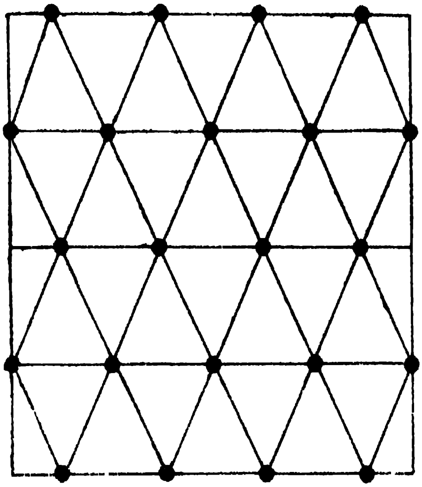


FIG. 5 TRIANGULAR

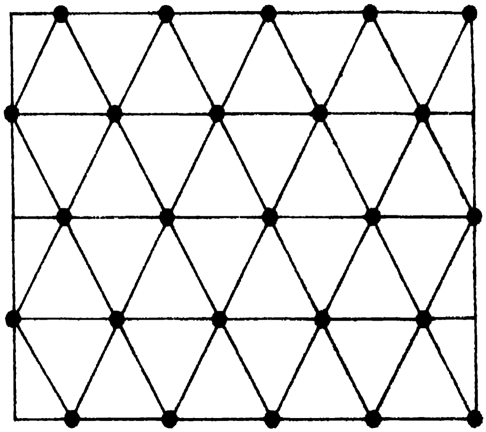


FIG. 6 HEXAGONAL

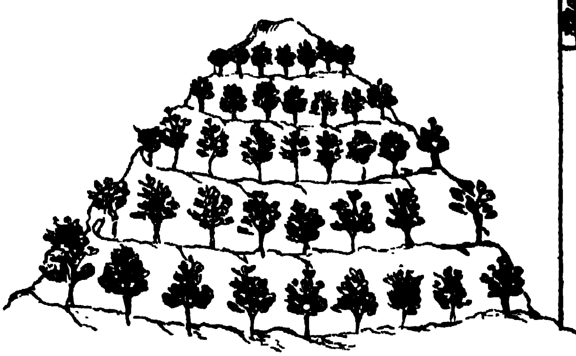
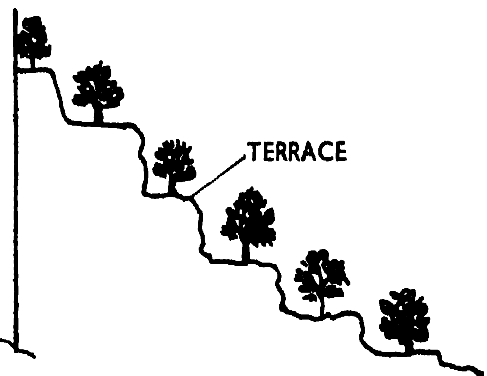


FIG. 7 CONTOUR



HILL

FIG. 8 PLANTING BOARD

5. Allow further extension of area from time to time so that subsequent plantings would match with the existing orchard planting (Naik, 1949).

System of Planting

The system of planting to be adopted is selected after considering the slope of land, purpose of utilising the orchard space, convenience, etc. Generally, six systems of planting are recommended for fruit trees.

1. **Square system**

This system (Fig. 2) is considered to be the simplest of all the systems and is adopted widely. In this system, the plot is divided into squares and trees are planted at the four corners of the square, in straight rows running at right angles. While laying out the plot a base line is first drawn parallel to the road, fence or adjacent orchard, at a distance equal to half the spacing to be given between the trees. Pegs are fixed on this line at the desired distances. At both ends of the base line right angles are drawn by following the simple carpenter's 3, 4, 5 metres system. After the formation of three lines it is easy to fix all the other pegs to mark the tree locations in between the lines at the required spacing by using ropes connecting the pegs of the lines in opposite directions.

Under this system, intercultural operations, spraying, harvesting, etc., can be done conveniently and easily. Planting of quick growing fruit trees like papaya, banana, guava during the early life of the orchard is possible. Raising of intercrops like vegetables, ginger, turmeric, cumin, coriander and such other spices can be done conveniently ; cultivation and irrigation can be done in two directions.

2. **Rectangular system**

In this system, the plot is divided into rectangles instead of squares and trees are planted at the four corners of the rectangle in straight rows running at right angles (Fig. 3). The same advantages which have been mentioned in the square system are also enjoyed here. The only difference is that in this system more plants can be accommodated in the row keeping more space between the rows.

3. **Triangular system**

In this system, trees are planted as in the square system but the plants in the 2nd, 4th, 6th and such other alternate rows are planted midway between the 1st, 3rd, 5th and such other alternate rows (Fig. 5). This system has no special advantage over the square system except providing more open space for the trees

and for intercrops. It is not only a difficult layout but cultivation also in the plots under this system becomes difficult.

4. Hexagonal system

In this system, the trees are planted at the corners of an equilateral triangle and thus, six trees form a hexagon with the seventh tree at the centre (Fig. 6). This system is generally followed where the land is costly and very fertile with ample provision of irrigation water. Though 15 per cent more trees can be planted in an unit area by this method over the square system, fruit growers usually do not adopt it, as it is difficult to layout and cultivation in the plot cannot be done so easily as in the square system.

For laying out the plot, a base line is drawn in one side as in the square system. Then an equilateral triangle having rings at each corner and with sides equal to the length of the required distance are made of heavy wire or chain. Two of these rings are then placed on the stakes of the base line and the position of the third ring indicates the position of a tree in the second row. This row is then used as the base line and pegs are set in the third row. In this way entire plot is laid out.

5. Quincunx system

This system of planting fruit trees is similar to square system, except that a fifth tree is planted at the centre of each square (Fig. 4). As a result the tree number in an unit area becomes almost double the number in the square system. The additional tree in the centre is known as "filler". The fillers are usually quick growing, early maturing and erect type fruit trees like banana, papaya, pomegranate, etc., which are removed as soon as the main fruit trees planted at the corner of the square come into bearing. The planting of filler trees provides an additional income to the grower in the early life of the orchard.

6. Contour system

It is generally followed on the hills with high slopes (Fig. 7). It particularly suits to a land with undulated topography, where there is greater danger of erosion and irrigation of the orchard is difficult. The main purpose of this system is to minimise land erosion and to conserve soil moisture so as to make the slope fit for growing fruits. So, the contour line is designed and graded in such a way that the flow of water in the irrigation channel becomes slow and thus finds time to penetrate into the soil without causing erosion.

The width of the contour terrace varies according to the nature of the slope. If the slope becomes stiff, the width of the terrace is narrower and *vice versa*. The

greater the width of terrace, the less the chance of erosion. The planting distance under the contour system may not be uniform. On mild undulated land, the terrace may be done after the trees are planted. Generally three types of terraces are adopted in contour planting. Among them bench terrace is the easiest to adopt and is very popular.

Spacing of Fruit Trees

Provision of optimum spacing to fruit trees is one of the most important aspects of successful fruit culture. If the spacing is inadequate, the fruit trees will grow poorly, produce small quantity of fruits of inferior quality, and suffer from various diseases and insect pests. The cultural practices of the orchards are also greatly hindered. Weeds and grasses grow in abundance and rob off the vitality of the trees, resulting in their early decline and premature death. On the other hand, if the spacing is too wide, there will be wastage of valuable orchard land without having any direct benefit on ultimate yield of the orchard. The optimum spacing is, therefore, desired so that the fruit trees may grow and bear crops properly. The optimum spacing is one in which the tree on attaining its full size will not touch the branches of the neighbouring ones and the root-system of one tree must not encroach that of the adjoining tree. The spacing given to fruit trees is generally governed by the following factors :

1. Climate and soil

Under favourable climatic condition and fertile soil fruit trees are likely to grow vigorously, and thus require wider spacing.

2. Varieties

Varieties which produce bigger-sized trees require greater spacing than those producing smaller-sized trees.

3. Growth habit

Fruit trees having spreading growth habit (mango, jackfruit, cashew nut, litchi, sapota, etc.), should be given more spacing as compared to less spreading fruit trees (coconut, banana, papaya, kagzi lime, orange, etc.).

4. Rootstocks

Fruit trees grown on vigorous rootstocks require larger spacing than those grown on dwarf rootstocks.

5. **Nature of irrigation**

Trees grown under liberal irrigation attain bigger size than those under restricted irrigation and require relatively wider spacing.

6. **Pruning**

As pruning determines the size of the tree, the spacing will vary according to whether the trees will be pruned as standards, half standards or bushes.

It is very difficult to suggest the exact spacing for fruit trees which will suit every locality or soil. However, the spacing given below for some of the important fruits may be considered as a safe guide for planting fruit orchards both in the hills and plains :

	Fruits	Spacing (metre)
1.	Pineapple	0·45–0·60 × 0·30–0·45
2.	Banana, papaya, grapes	2–3 × 2–3
3.	Phalsa	3 × 3
4.	Passion fruit	3–4 × 3–4
5.	Pomegranate	3–6 × 3–6
6.	Custard apple	4–5 × 4–5
7.	Date palm, fig, lemon	5–6 × 5–6
8.	Pumelo, grapefruit	6–7 × 6–7
9.	Guava, cashew nut, mulberry	6–8 × 6–8
10.	Persimmon	7–8 × 7–8
11.	Sapota, loquat, avocado, starapple	8–9 × 8–9
12.	Mandarin orange, sweet orange	6–9 × 6–9
13.	Aonla, mangosteen	9–11 × 9–11
14.	Ber, jamun, mango, litchi	10–12 × 10–12
15.	Jackfruit, breadfruit	12 × 12

Preparation of Land

Before laying out of plots and digging the pits, the orchard land should be prepared well by repeated ploughing, harrowing and levelling. If possible green manuring crops like dhaincha, sunhemp, cowpea, etc., may be raised and ploughed down during land preparation to enrich the orchard soil and improve its physical condition.

Digging of Pits

After deciding the system of planting to be followed and the planting distance to be given to the orchard trees, the selected plot is laid out with the help of a measuring tape, chain, pegs, etc. Then the pits around the pegs so fixed are dug well in advance of planting. To facilitate planting at the right position, a planting board consisting of an wooden plank 152 cm long, 10 cm wide and 3 cm thick having three notches at a distane of 45 cm from each other is used (Fig. 8). The central notch is placed over the marking peg and two pegs are then driven in the notches at the ends of the board. The board and the marking peg is then removed leaving the end pegs as guides to dig the pit at the right position.

The size of the pit varies according to the nature of soil and the size of the fruit trees to be planted. Generally, larger pits are dug in poor soil and for large sized fruit trees, whereas smaller ones are dug in a richer soil and for dwarf fruit trees. The pit size, in general, varies from 0·6 m cube to 1 m cube. While digging pits, the top soil up to a depth of 45 cm and subsoil below this should be placed separately. After complete digging the pits are exposed to the sun for a couple of days for disinfection of the pit soil. The pits are then filled up with top soil mixed with farm-yard-manure or compost or tank silt, bone meal and wood ash, up to at least 10 cm above the ground level. The pit soil should also contain a certain amount of gammexane (10 per cent) or aldrin (5 per cent) to prevent white ant. Before the planting is taken up, the pits should receive a couple of good showers of rain or water should be applied to them so that the soil settles down properly.

Selection of Planting Materials

Generally, vegetatively propagated materials such as cuttings, layerings, buddings, grafts, suckers, etc., and sometimes seeds and seedlings are used to raise an orchard. The selection of suitable and genuine plant material is very important so far as the profitability of the orchard is concerned. It is always safer to collect plant materials at a higher rate from a known and reliable source than purchasing cheaper materials from an unknown source.

The characteristics of good planting materials are—

(i) They should be true to variety and prepared from healthy mother plants with high productivity.

(ii) They should be healthy, stocky and of proper age but not too old.

(iii) They should not have been budded or grafted higher than 20 cm to 30 cm from the ground, and the graft or bud joint should be clean as far as practicable.

(iv) They should have clean trunks, abundant roots and vigorous top growth with uniformly spreading branches all around the trunk.

(v) Their roots should be free from knots and should have sufficient lateral and fibrous roots.

(vi) The planting material should have no sign of physical damage and of insect and disease attack.

(vii) They should be certified by proper authority.

Planting

The most important factor that influences the time of planting is the rainfall. Where the rainfall is not heavy fruit trees can be planted in the beginning of monsoon but in areas with heavy rainfall planting should be done when the monsoon is over. Planting should be avoided, however, during hot and dry spells of weather. The fruit trees should preferably be planted in the afternoon and on cloudy and humid days rather than in bright sunshine and dry weather.

The points to be taken into consideration during planting are—

(i) Dig out only a small amount of soil in the centre of the covered pit to accommodate the ball of earth around the root of the planting material in case of evergreen fruits or the naked root portion in deciduous fruits.

(ii) Place the planting material erect in the hole, determine its exact position with the help of a planting board and see that the roots are in their natural position. Fill the hole with the dug out soil and press gently.

(iii) Apply water immediately after planting just to wet the pit soil without any stagnation.

(iv) Do not bury the bud or graft joint of the planting material in the soil. Plant at the same depth as in the nursery bed or in the pot.

(v) The plants should be staked with a bamboo pole to prevent lodging and damage to bud or graft joints by strong wind. In hilly and dry areas the *in situ* method of planting of fruit trees is very useful. In this method healthy and mature seeds of suitable rootstocks are sown in the prepared pits. After the seed has germinated, it is trained to a single stem and is allowed to grow for nine months or more, when side or veneer grafting is done using superior scion material. By this system of planting the unaffected tap root of the rootstock can easily go deep into the soil layers for reaching the underground water and thus helps in better survival of the scion plants.

Intercropping

The fruit plants in the orchard take some years to produce the first crop. This period differs from species to species, and among the varieties also. The

orchardists do not get any return from the new orchard till this period is over. Hence, it is necessary that intercrops should be grown in the space between the rows of the young fruit trees, following usual package of practices for growing such crops. This will help the orchardists to get some income even in the initial years. Besides, the orchard receives regular cultivation and attention and due to that weeds are checked, pests and diseases are controlled to some extent. The young fruit trees sometimes receive partial shade which is beneficial to them. Sowing of leguminous crops and cover crops adds to the fertility of the soil and conserves the orchard soil, respectively.

In selecting the variety of crops to be sown as intercrops, attention must be given to the requirements of the main crop. The intercrop should not exhaust the orchard soil too much. Usually quick growing and early bearing fruit trees like pineapple, papaya, banana, guava, phalsa, etc., vegetables like cabbage, cauliflower, potato, pumpkin, tomato, melon, bean, etc., and spices like chilli, ginger, turmeric, etc., are grown as intercrops.

Research studies indicate that coconut growers in Kerala use inter/mixed crops in the coconut plantation to the extent of 78 per cent, and tapioca occupies 20 per cent of such gardens (Krishna Marar, 1964). In Andhra Pradesh 34·7 per cent of the coconut gardens have inter/mixed crops with banana, mango, citrus and turmeric. In Tamil Nadu, 65 per cent of the coconut gardens have rice, sugarcane, sorghum, tapioca and vegetables. In Philippines, ginger, groundnut, colocasia and pineapple are widely grown as intercrops (Nelliat and Shama Bhat, 1979).

Thus, it is essentially felt that, while planning an orchard, the spacing of the main fruit crop and the intercrops selected should be planned according to the suitability of such crops, facilities available, environmental conditions prevailing, financial condition of the farmer and demand for such harvest by the consumers. While planning the orchard these should be indicated in the plan beforehand.

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3

ORCHARD SOIL MANAGEMENT

SANT RAM and S. RAJAN

Orchard soil management is one of the most important aspects of the orcharding. Soil serves as a reservoir for the supply of nutrients to the orchard trees which is affected by different soil management practices, such as manuring, tillage, drainage, intercropping, etc. Properly managed soils perform as an inexhaustible source of nutrients for the trees. Therefore, the properly managed soils are those which have proper physical condition and maintain the essential plant nutrients and can also be in a position to supply the nutrients to the tree as and when they are needed. Some factors which affect the supply of nutrients to the tree are soil structure and texture, parent material, organic matter content, pH and intercropping, rainfall, leaching of nutrients, waterlogging, etc. In the following paragraphs it will be discussed how to manage orchard soil to maintain continuous supply of nutrients to the trees without affecting the soil fertility and also aspects related to the improvement of the orchard soil.

Nutrients and Their Availability

Deficiency of different nutrients may occur under many conditions. Sandy soils of high rainfall area and low in organic matter content are generally considered to be deficient in nitrogen. In heavier soils nitrogen accumulates in upper layers of the soil but this accumulation pattern is reversed in lighter soils. Nitrogen tends to move deeper in soils having more sand and gravel content.

Phosphorus is not readily available in calcareous soils, although the soil may have high phosphorus content. Highly weathered soils are acid in reaction and generally deficient in available phosphorus. Exchangeable cations, clay minerals, iron, aluminium, calcium carbonate and organic matter are principal factors responsible for phosphorus fixation in the soil (Wild, 1950). More than 90 per cent of fixed phosphorus in Indian acid soils was recovered as precipitated iron and aluminium phosphates (Ghani and Islam, 1946).

Light and acid sandy soils are low in potassium (Gilbert, 1957). Soils heavily cropped, leached and eroded also lack in potassium content. Potassium fixation in non-replaceable form creates potassium deficiency in soils.

Acid and sandy soils of humid regions are often low in calcium. In alkali or sodic soils with high exchangeable sodium and high pH plants may not be able to absorb calcium from soil due to extreme insolubility of calcium compounds. The low supply of exchangeable calcium may also occur in the presence of a considerable excess of sodium over calcium (Chapman, 1975).

Generally magnesium deficiency occurs in acid and sandy soils of moderate to high rainfall areas. Light textured soils are more prone to magnesium loss than heavy soils. Addition of supper phosphate and potassium sulphate in large amounts also increases rate of magnesium leaching.

Ferrous content increases with the decrease in pH (Singh, 1964). Availability of iron is decreased in alkaline calcareous soils. In presence of bicarbonates iron availability is decreased and often chlorosis occurs in fruit trees. Light coarse textured soils may lack available iron. Deficiency may also occur in poorly drained soils.

Alkaline soils lack in water soluble manganese. Soils containing high amount of organic matter may produce deficiency symptoms in fruit plants due to formation of unavailable manganese complexes. Calcareous soils having high amount of calcium carbonate are deficient in available manganese due to adsorption of manganese on the calcium carbonate particles. Very sandy soils derived from the low manganese parent material are deficient in available manganese. Calcareous soils having high organic matter and poor drainage also lack available manganese. Fine textured soils are more rich in available manganese than coarse sandy soil.

Molybdenum is available in low amounts in acid soils and liming increases molybdenum availability (Anderson, 1956). Certain well-drained calcareous soils are also deficient in molybdenum. Increase in clay content of soil increases availability of molybdenum (Kavimandan *et al*, 1964).

In acid soils the available copper may leach with drainage water. Fixation of copper in the soil is increased above pH 5·5. In highly organic soils copper deficiency may occur due to fixation (Kanwar, 1954). The presence of nitrogenous and potassic fertilisers reduce the adsorption of copper in soils (Misra and Tiwari, 1964).

Zinc is not easily available to plants in alkaline soils. Deficiency may occur in acid and sandy soils also. In some organic soils zinc is bound and is not readily available to plants. However, zinc deficiencies are more common in calcareous soils. Soils containing abnormally high amounts of soluble phosphates may lack in available zinc. Soils containing clays with low Si/Mg ratios are also deficient in available zinc because zinc is fixed in these soils (Elgabaly, 1950).

Soils derived from material containing low boron, such as acid igneous rocks, are deficient in boron (Mitchell, 1955). Alkaline soils containing free lime and

over limed soils are deficient in available boron content. In light-textured sandy soils, boron is available in small quantities but in fine-textured soil boron fixation may also take place (Singh and Kanwar, 1963). Soils, low as well as very high in organic matters are deficient in boron content and drought further aggravates its deficiency. The problem of internal fruit necrosis in mango, aonla and guava as well as browning and spongy tissue formation in jackfruit are due to boron deficiency (less than 0·6 ppm) where orchard soil pH ranges from 6·5 to 8·5 and soils are also rich in calcium and carbonates (Ram *et al*, 1976, 1978 ; Ram and Tewari, 1977, 1978).

Soil pH is an important factor in relation to nutrient availability in soils and absorption by plant roots. It affects the plant growth directly or indirectly by modifying the metabolism or availability of plant nutrients. In extremely acid soils (pH below 4) direct plant injury may occur due to interactions with hydrogen ions. Under acidic conditions, levels of nutrient cations (calcium, magnesium and potassium) are low. Generally, the degree of base saturation of these soils is also below the critical level for the proper plant growth. At low pH, solubility of aluminium and iron is increased and they react with phosphate and make it unavailable to plants (Hemwell, 1957; Troug, 1948).

High acidity also favours the solubility of manganese, copper, zinc and other heavy metals and they may create toxic conditions for plants. Molybdenum is the only micronutrient of which availability is limited in acid soils and, if the pH is increased up to 6 or above, the availability is increased (Buckman and Brady, 1974).

Organic Matter Maintenance and Water Relations

Soil organic matter includes the highly decomposed and colloidal soil fraction known as humus as well as organic residues which have not lost atomic structure (Kanonova, 1961). Organic substances play important role in formation of fertile soils, as they are the sources of plant nutrients which are liberated in soluble forms after breakdown of organic matter. Besides, as a source of plant nutrient, it serves many other purposes ; such as improvement of soil structure, drainage, aeration ; increases it also the water retaining capacity, buffering capacity and resistance to erosion (Bermner, 1956).

Organic matter serves as a source of energy for microbes and organic acids produced during decomposition which helps in dissolving minerals, such as potassium and its availability to plants. Some of the intermediate compounds form chelating ions and phosphorus and micronutrients attached to these ions are in weakly ionised state and they are retained against fixation by soil, but remain in a form that can be utilised by plants (Singh and Lal, 1976).

Plant species may differ with each other for root distribution and their water utilising efficiency from different layers of the soil. The soil may act as reservoir for water if rain water enters the soil and surface runoff is minimised. Organic matter increases infiltration of water by improving the physical conditions of the soil. Under such conditions less time is required by water to reach root zone in the soil.

Water retention within the root zone is dependent upon characteristic of soil and on its depth. In sandy soils organic matter increases the storing capacity of available water but in other soils no significant effect has been noticed (Jaimson, 1956). Soil aggregation and aeration are improved with the addition of organic matter but bulk density is decreased.

For efficient production water is needed in effective amounts but soil should not have excess of it. Organic matter also plays a key role in conditions where water is in excess by improving aggregation, aeration and increasing root growth. To maintain different physical and biological conditions necessary for plant growth, optimum level of organic matter is important. Organic manure supplies many plant nutrients, along with organic matter for the improvement of soil. The total benefit of these manures cannot be judged immediately because nutrients are held in humus like compounds which release nutrients slowly for many years. Composts are good source of organic matter.

Green manures are often grown for maintaining organic matter content of the soil. Crops like dhaincha (*Sesbania aculeata*), sunnhemp (*Cortolaria juncea*), urid (*Phaseolus mungo*) and indigo (*Indigofera hirsuta*) can be used as green manures. Along with organic matter supply to the soil, green manuring serves other purposes such as weed control, improvement of soil structure, enriching nitrogen content of soil and soil conservation. These crops are often taken in rainy season and also serve the purpose of cover crops and reduce soil erosion.

Orchard Soil Management Practices

Most of the orchard cultural practices involving soil are related with moisture supply, soil erosion, nutrient availability, soil aeration, etc. Therefore, one has to be careful in orchard cultural practices. Orchards differ with each other for their requirements for cultural practices due to different conditions which involve factors, viz., type of fruit crop and its growing habit including root distribution, moisture and nutrient requirements, topography of soil, climate, type of weeds, etc. Thus specific cultural practices cannot be recommended for all orchards without restrictions. However, following are the principal objectives which should be kept in mind before employing cultural practices in the orchard.

1. To create favourable conditions for moisture supply and proper drainage.

2. To maintain sufficient soil organic matter and its replenishment against losses caused by different factors.
3. To check and reduce soil erosion.
4. To provide proper aeration necessary for gaseous exchange and microorganism activity by maintaining soil in loose and friable condition.
5. To supply sufficient nutrients needed for vegetative growth and development of fruit plants.

Soil management practices such as clean cultivation with cover crop, intercrop, artificial mulch, etc., are various systems used in different parts of the world. Clean cultivation involves the ploughing or discing of the land in the winter months or in spring. These operations may be done according to the needs of the orchard. Any crop other than the main fruit crop which is grown in between the trees is an intercrop, whereas those raised specially for enriching the organic matter of soil are in general, green manure crops. The cover crop is that which protect the soil with its vegetative cover and it may also be used later on as green addition to ploughing a cover crop is grown manure which is ploughed in after manure crop. Weeds are sometimes allowed to grow instead of growing any crop before winter ploughing. This practice is useful in conserving moisture, increasing organic matter and checking erosion and surface run-off.

Cultivation of orchard soil is important to remove weeds, incorporate fertilisers and green manure and to facilitate absorption of water in the soil by breaking imprevious layer formed due to other operations. Deep tillage is not important in orchards, except before planting of fruit plants, because it may cause injury to the roots of the trees. In citrus, root-rot disease occurs commonly in orchards where root injury is frequent (Naik, 1949).

Clean cultivation

Cultivation plays a significant role in killing of weeds which is responsible for removal of large amounts of moisture and nutrients, particularly available nitrogen. Sometimes weeds are helpful in creating suitable conditions in which pests and pathogen may easily complete their life cycles.

Physical condition of loam and clay soils is very much influenced by the previous tillage. Cultivation is also important to keep soil surface free from hard layer. Tillage loosens the soil which improves infiltration. The soil surface becomes rough due to the formation of depressions, pockets or furrows that creates obstacles to the flow of water and water uptake by the soil is increased (Burwell *et al*, 1966).

Freshly cultivated field is susceptible to water erosion and gully formation. This type of erosion may occur in warm humid regions. In semi-arid regions, where soil surface often remains dry and exposed in most part of the year,

cultivation favours wind erosion (Allison, 1973). According to Chepil and Woodruff (1963) for better protection against the wind, maintenance of vegetative materials on the surface should be preferred instead of mixing them into the soil at the initial stages to increase soil aggregation.

Biological activities of the soil are also increased due to better aeration as a result of cultivation. Tillage exposes an inch (2·5 cm) or so of top soil to rapid drying, and after each drying the biological activity is increased to a great extent for a period of three days following remoistening.

Sod culture

Certain temperate fruit trees can grow well without tillage but this condition does not exist in subtropical and tropical parts of India (Hayes, 1966). Sod system is most commonly applied in cool and moist regions of Europe and America, where fruit trees are grown without any tillage or mulching with litter. The grass may remain without cutting, but it is usually cut once or more in a year. This grass may be removed from the orchard or left to lie on the ground (Gourley and Howlett, 1957). Although having certain advantages in cooler and moist region, the system creates unfavourable conditions for fruit trees by reducing soil moisture and nitrogen level. Available nitrogen is utilised by the vegetation growing above the ground and significant amount of nitrate are used for the decomposition of organic matter by microbes due to the low nitrogen content of the same.

In the plains of India, sod is not recommended in orchards due to scarcity of available nitrogen and moisture in most part of the year (Hayes, 1966). Striking effect of sod on longevity and vegetative growth of different fruit species was recorded at Pusa. In the experimental plot sodded with *doob* grass (*Cynodon dactylon*), custard apple plants died in two years, whereas loquat lived for five years, plums for seven and limes for eight years. Guavas thrived for the maximum time but they were half in height compared to those under clean cultivation (Howard, 1925).

Mulching

The term mulch refers to the cover of materials like straw, hay, crop residue, petroleum products, etc., spread over soil surface. Sometimes cover crops are also grown as mulch especially in tropical and subtropical conditions, with their long growing seasons. Precisely it is a surface barrier preventing evaporation.

Various types of materials are in practice as mulches including natural and synthetic products. Manures, straw, sugarcane trash, leaves, peanut hulls, wood products, various kinds of litters and sawdust are commonly used as mulches. Now-a-days, in specific crops, clear or coloured polythene sheets, (Srivastava and

Agrawal, 1965), papers, granular coke (Quashu and Evans, 1967) and wood fibre cellulose (Barkley *et al*, 1965) are also used as mulches.

During summer months soil moisture is considerably reduced which causes severe fruit drop in citrus, if trees are not irrigated frequently (Sinha *et al*, 1978). Sometimes due to limited sources of irrigation it is not possible to irrigate orchard frequently during summer months. Krishnamurti (1959) recommended mulching with leaves, as a standard practice for citrus orchards of North India to tide over high soil temperatures and rapid evaporation of soil moisture during high atmospheric temperatures and low humidity.

Randhawa *et al*, (1960) used different materials as mulch in sweet orange trees and observed that the minimum loss of soil moisture was recorded where black polythene was used. Results of experiments conducted at California revealed that mulching is more beneficial than clean cultivation in citrus orchards (Chandler, 1956). At Coorg (South India) better moisture conservation, weed control and soil organic matter maintenance were recorded in citrus orchards by mulching (Aiyappa, 1967).

Mulches are widely used in tropical regions for fruit crops such as citrus, banana and pineapple. Banana trash is commonly used in banana plantations. Sherman and Fujimoto (1946) observed considerable reduction in soluble manganese content in Hawaii in pineapple soils with the use of mulch where high availability of manganese is a problem.

The most useful type of mulch is that which absorbs little moisture, does not pack or form a water shedding type of surface and allows the rainfall to move downwards rapidly into the soil. Straws and leaves are considered as better mulching materials. Very sandy soils are not much benefitted by mulching except for weed control, because infiltration and moisture loss due to capillarity is not a problem with these soils (Allison, 1973). Mulches do not compete with fruit trees for moisture and nutrients and they conserve moisture by suppressing weed growth, lowering soil temperature and by decreasing surface evaporation. Under a mulch, root growth is increased, leaching is diminished and soil structure is improved. Mulches have their favourable effects on nutrient availability also. Short supply of nitrogen may occur in some cases due to high C/N ratio of the mulch and nitrogen fertilisation is needed. According to Jacks *et al*, (1955) nitrification is increased under paper mulch in Hawaiian pineapple soils. He also referred the same pattern of nitrification under a mixed mulch in Trinidad cocoa soils.

Mulching may improve soil structure and aeration by reducing raindrop impact and preventing crusting on the soil surface. Mulch acts as an insulation and thus damp down effects of sudden fluctuations in air temperature. It also reduces heat loss from the soil surface during night and keeps temperature low in day time in the tropics.

Cover crops and green manures

Cover crops are used particularly in the areas where orchard soil is eroded during rainy season and drainage is poor. These are grown between the trees in the orchard and turned into the soil prior to or at the time of crop maturity to protect against soil erosion and nutrient losses besides adding organic matter into the soil. The cover crops are especially advantageous when compost and farm manures are not available and nutrient requirement of fruit trees can be met by adding cover crops into the soil without any adverse effect. These crops also increase water retaining capacity and improve the biological complex of the soil. Legumes are preferred as cover crop because they add extra nitrogen through nodules which is fixed from the atmosphere. The cover crops also kill and supress the weeds in rainy season. Crops such as mung, urid, cowpea, guar, soyabean, etc., are preferred as kharif cover crops, whereas in rabi season senji (*Melilotus parviflora*), pea (*Pisum sativum*), lentil (*Lens esculenta*), moth (*Phaseolus aconitifolius*), methi (*Trigonella foenungraecum*) broadbean, etc., are used. Cover crops should be such that its water requirement corresponds with the water requiring timings of the tree, otherwise irrigation may have bad effect on the trees. Mango trees should not be irrigated from October to December under Northern Indian conditions, coinciding with the period of flower bud differentiation. It is well documented fact that irrigation adversely affects fruit bud differentiation in mango and drought favours it. Therefore, crops like berseem which require heavy irrigation from October to December should not be cultivated even though it is a legume.

When green manures are grown for the purpose of soil improvement, it is better to incorporate the crops into the soil while they are in succulent stage. But sometimes they are allowed to grow for much longer period for the purpose of soil protection, where erosion is a problem. If clean cultivation is followed, significant erosion may occur in rains and probably it is best to plant some green manure crops between the trees early in the rains and plough it into the soil towards the end (Hayes, 1966).

Generally, leguminous green manures are preferred, but Batchelor (1949) recorded that nitrogen fixation by the bacteria associated with legume may not be in appreciable amounts when the nitrate is present in large quantities in soil, particularly in mature citrus orchards.

Intercropping

Fruit trees take long time to provide profitable yields to the grower. Therefore, it is desirable that fruit growers should cultivate short-term crops till tree canopy enlarges to the extent that the whole field is shaded. Intercropping is an important operation in the non-bearing young orchards. However, the intercrops should be given secondary importance. The intercrops which grow very tall, or spread rapidly, viz., cucurbits should not be used. They should not be allowed

to grow between the stem and the drip of the tree. The water requirement of the fruit crop and the intercrop should invariably coincide. Intercrops should be such that do not exhaust nutrients and moisture of the orchard and crops such as sugarcane, maize, jowar, etc., which are heavy feeder should be discouraged and annual crops particularly, legumes should be preferred in their place. Most of the vegetables which do not have deep root system should also be encouraged for intercropping such as tomato, onion, beans, radish, palak, etc. However, additional doses of fertiliser should be provided for maintenance of intercrops, failing which the health of the orchard will be adversely affected.

Some fruit trees can also be cultivated as intercrops. However, the above mentioned principles should be applied in the selection of the fruit trees. These fruit trees which are used as intercrops are also known as filler trees. Among the fillers pineapple, strawberry, phalsa, papaya, etc., are more appropriate which generally take about two years to produce the crop. In case of mango some long duration fruit trees but dwarfer than mango can also be used as fillers, such as peach, plum, guava, pomegranate, etc., whose irrigation and fertilising timings coincide with mango. However, additional doses of fertilisers according to their requirement should invariably be provided to these fillers.

It is observed that many a time farmers cultivate wheat, oat, jowar, bajra like crops as intercrops in the orchard. Such crops adversely affect the fruit production particularly in mango when their grain formation timings coincide with flower bud differentiation in mango and they extract maximum amount of moisture and nutrients from the soil and deplete the main fruit crops. Similarly ginger, calocasia, turmeric which are heavy feeder, should also be avoided. Experiments conducted at Pantnagar have shown that severe defoliation of mango trees occurred when ginger was used as intercrop. G B. Pant University of Agriculture and Technology, Pantnagar, recommends following intercrops for bearing and non-bearing orchards.

A. *Bearing Orchards*	B. *Non-bearing Orchards*
Tomato, Feb.-June	Soyabean, June-Sept.
Cowpea, July-Sept.	Pea, Oct. March
Soyabean, June-Sept.	Cowpea, June-Sept.
Coriander, Dec.-April	Palak, Oct.-Feb.
	Chillies, March-Aug.

Orchard Soil Improvement

Different soil management practices can improve the orchard soils, having various disorders such as, poor drainage, salinity, alkalinity, acidity or coarse texture.

Fine-textured and poorly drained soils

Removal of excess water from the soil is also very important for fruit trees. Poor drainage causes salt accumulation in arid zones and other adverse conditions may develop, viz., poor aeration, low soil moisture and changes in soil structure. Sometimes irrigation water contains soluble salts which are concentrated in soil by transpiration and evaporation processes. To keep the salts in dilute condition, excess of water must pass out of root zone and it should be flushed away. Poor drainage has been suggested as one of the cause of citrus decline in different parts of India (Bhatt, 1945 ; Naik, 1949 and Kanwar and Randhawa, 1960). Excellent growth of citrus has been reported from the areas where the water table was below 1·5 meters throughout the year (Kanwar *et al*, 1965). The success of citrus orchards in fluctuating water table conditions would depend upon regulatory operations to keep the water table essentially static (Chapman, 1959, 1961).

Drainage system should be efficient to reduce the stagnated water and lower down the water table. Open or tile drains can help in keeping water table static (Chadha *et al*, 1970). Suitable drains will have to be constructed in order to remove excess water. Deeper drains may be required for lowering the water table. In the areas like Terai, where fluctuation in water table is common due to high seasonal rainfall, trees like citrus and papaya may be planted on ridges.

Root growth and its proper distribution in soil are important for tree growth. Aeration of soil is often a limiting factor for root growth and nutrient absorption. Tree roots are distributed deeper in aerated soils and function throughout the year including wet and dry periods. Due to respiration activity of roots and soil organisms, oxygen level of soil is reduced and carbon dioxide concentration is increased. These changes are more marked in soils having abundant organic matter and microbial activities with fluctuating soil temperatures. Diffusion of oxygen in the soil is influenced by temperature changes, local air movement and downward percolation of water (Schroeder *et al*, 1965). The rate of gaseous exchange is influenced by soil texture and structure. Aeration is not a problem in sandy soils but the condition is quite opposite in fine-textured soils. Movement of oxygen is restricted in a more specific way in soils having less than 10 or 12 per cent of their volume consisting of non-capillary pore space (Robinson, 1964).

Bain and Chapman (1940) studied that citrus and avocado roots are not injured in an atmosphere with as low as 10 per cent or higher carbon dioxide. Reduction in the size of the pore-space occurs due to trampling or working soils while they are wet. Roots of trees are deep in soil where gaseous exchange may be slow. Thus care to avoid puddling orchard soils is even more important here than in other crops.

Beside the root growth, aeration also affects water and salt absorption, water balance, photosynthesis and susceptibility to root diseases. Roots produced in poorly aerated environments are thick and contain larger air spaces and are more in number. Sudden decrease in aeration causes wilting and water deficit which reduces the photosynthesis rate. Poor aeration creates favourable conditions for pathogen and poor growth of roots. Many pathogenic species grow in poorly aerated soils and injuries to citrus and avocado roots are reported.

The rate of fruit drop may be more in poorly aerated soils. Dropping of fruits is sometimes continued up to full maturity due to the unsatisfactory water supply from the weak and poorly aerated roots during the period of high transpiration. Possibly, it may be due to the toxins produced as a by-product of fermentation, passing up through water stream and accelerating abscission of the developed fruits. Waterlogging has been reported to increase ABA (inhibitor) content in roots and aerial part of the plants, which may sc+ in abscission of leaf and fruit, and also may be injurious to roots.

In the process of improvement of poorly drained soil, the most important step is to get rid of excess water by suitable surface or sub-surface drainage. In low lands, especially dealing with fine textured soils where water tends to accumulate, ploughing or spading should be delayed until the field is sufficiently dry. Replenishment of organic matter in humid regions is one of the most important management practices. Organic matter can be supplied from external sources such as crop residues and organic manure. Cultivating deep-rooted legumes and turning them into the soil is the easiest method of increasing organic matter content.

Coarse-textured soils

These soils are characterised by very low content of inorganic and organic colloids, lack of nutrients and low water-holding capacity which are responsible for low productivity. These soils may be useful in production of some vegetables and small fruits. However, adequate fertilisation and irrigation are needed for shallow rooted crops. Fruit crops may thrive well due to their deep root systems (2-3 m), but irrigation becomes a limiting factor in some parts of the year.

Incorporation of organic matter in very sandy soils can significantly improve the fertility by increasing ion-exchange capacity. The exchange capacity of organic colloids is about half of the total colloids (Allison, 1973). Regular supply of animal manure and crop residue can maintain the organic matter level. The maintenance of high level of organic matter is difficult due to rapid biological oxidation. After decomposition of organic matter it disappears rapidly in coarse-textured soils. However, crops such as cortolaria, sunnhemp, etc., can be grown and added to the soil.

Saline and alkaline soils

About 7 million hectares of land in our country is affected by salts and salt accumulation is the most serious problem of arid zones (Jindal *et al.* 1976). Apart from influencing plant metabolism directly, salts inhibit the absorption of water and nutrients and certain ions may show signs of toxicity after being absorbed.

Soils containing excess soluble salts (chlorides, sulphates, carbonates or bicarbonates of calcium and magnesium) are known as saline soils; whereas, soils having high contents of adsorbed sodium are considered as alkaline soils. Leaching of soluble salts with water having low salt content can improve these soils; but sodium held with exchange complex makes it difficult to handle. Inadequate drainage may lead to salinisation.

The degree of salt tolerance in fruit plants varies with species and also with the variety. Most of the fruit crops are highly sensitive to salts and should not be planted in saline or alkaline soils (Thorne and Peterson, 1954). In mango sodium chloride causes maximum leaf injury followed by sodium carbonate and sodium sulphate (Bhambota *et al*, 1963). Chloride toxicity in mango has been reported causing scorching of leaves (Pandey *et al*, 1971 ; Jindal, 1976).

Guava can tolerate several salts up to 0·35 per cent and sodium sulphate up to 0·525 per cent without any mortality (Desai and Singh, 1980). The growth suppression is more marked under chloride and carbonate salinisation than under sulphate salinisation. Desai and Singh (1980) observed scorching and inward curling of leaf margins in guava due to chloride toxicity.

Date-palm has been reported to be very tolerant to salts. It can grow in soils containing 3 to 4 per cent of white alkali, but the palm's roots must be in a stratum with less than 1 per cent of alkali salts (Singh *et al*, 1963). Citrus is very susceptible to salt injury. After analysis of large number of soil samples from chlorotic and healthy orchards it is proposed that electrical conductivity of 1 : 2 soil-water suspension should not be more than 0·5 m mho/cm (Kanwar and Randhawa, 1960 ; Kanwar *et al*, 1965).

Efforts to remove the surface accumulation of salts by lateral flushing with a head of water have not proved feasible in most of the cases (Chapman, 1975). This practice has been partially effective. If the salts are leached downwards out of root zone, shallow rooted fruit crops can be cultivated. For the conversion of alkali carbonates into soluble salts gypsum and sulphur are used. Gypsum (calcium sulphate) reacts with sodium carbonate and converts it into sodium sulphate (leachable). It is incorporated in the upper surface. However, it should not be ploughed deep. The soil is kept moist to hasten the formation of sodium sulphate and later supplemented by leaching of soil with irrigation water free from salts. After oxidation sulphur yields sulphuric acid when incorporated in soil. This changes the sodium carbonate into calcium carbonate and sodium sulphate.

For controlling further salinisation following points should be kept in mind : (i) excess of irrigation should be avoided ; (ii) frequent light irrigations are necessary to keep salts sufficiently dilute to allow normal plant growth (Buckman and Brady, 1980); (iii) salt tolerant crops (sugar beet, garden pea, carrot, tomatoes) should be grown and (iv) organic manures are very useful in these conditions.

Acid soils

For maximum fertiliser use and soil fertility, it is essential to induce ideal plant root environment by maintaining appropriate pH and base saturation in the soil. For this purpose lime is only potent source in acid soils. In these soils aluminium, iron or manganese are highly toxic to plants due to their availability in higher amount under low pH conditions. In humid climate, due to increased permeability of water into the soil from precipitation, large amount of basic cations is leached out leaving behind acid cations. After some years of regular leaching of these cations, application of lime is needed to maintain the level of basic ions for proper plant growth.

The quantity of lime required for neutralising soil acidity up to a desirable pH or converting soil conditions into less toxic depends upon several factors such as, type of parent material, clay content, vegetation, moisture, slope, etc. Numerous methods for determination of lime requirement have been developed and most often pH is considered as an indication for lime requirement. However, pH test indicates active acidity of the sample with no clear picture of the amount of residual acid-forming potential (reserved acidity). For adequate lime requirements both type of acidity should be determined.

For a specific pH, lime requirement increases with the decrease in soil particle size. The amount of calcium carbonate may be about 1 tonne per hectare for sandy soil and about 3·5 tonnes for clayey soils which may increase pH from 4·5 to 5·5.

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4

TRAINING AND PRUNING OF TROPICAL AND SUBTROPICAL FRUITS

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The fruit trees if left to grow for themselves, do not bear abundantly unless trained or pruned to a specific form. The pruning of plants is considered as one of the important horticultural operations and dates back to the ancient literature mentioned in the early days. In the ancient European literature there is mention of various training methods depicted by drawings. Bedford and Pickering, who were the first to publish results of pruning experiments describe it 'as an art it does not lend itself very freely to scientific investigation and where scientific investigation can be brought to bear on it, the teachings of the artist have not always been confirmed'.

Only during the last quarter century, the results of experiments on the effect of pruning upon growth and fruiting have been published. The art is still interwoven with the science to a considerable degree and all pruning practices, when critically examined, cannot be said to have a firm scientific basis.

Pruning is defined as the art and science of cutting away a portion of the plant to improve the shape, to influence its growth, flowering and fruitfulness, to improve the quality of the product or to repair injury. On the other hand, the growth habits of plants are characteristic. Though they cannot be altered but can certainly be modified by inducing the top growth. The control on the direction of the growth is known as training. It is also known as pruning for form.

There is frequent failure to distinguish between pruning and training clearly. Primarily training concerns form and pruning affects function. Training determines the general character and even the details of the plant's outline and

of its branching and framework, while pruning is meant to assist more in determining what the tree does in respect to fruiting. Before going to the main topic of pruning and training of different types of tropical and subtropical fruits, it is worthwhile to discuss the general aspects of pruning and training.

4.1 Pruning for Form

Comparatively, a large part of the training that the trees are to receive should be given during the first few years of their growth. It is during this period that their framework is builtup. In general, training has little effect on the amount of fruits borne. Some of the pruning practices that accompany certain methods of training may affect yield profoundly but the training in itself is of secondary importance. On the other hand, training may be a factor in determining the grade or quality of the fruit. Its influence on grade is produced largely through making the plant accessible for spraying thoroughly and consequently in aiding control of insects and diseases, because standard control measures for certain pests may loose half of their efficiency if plants are untrained or partly trained.

In certain fruits, the shape and openness of the tree are important in influencing the colouration. Training is also important in reducing certain production costs. Tillage and other soil treatments, spraying, propping, trellising and harvesting may be greatly facilitated by proper training. Training should also provide the leaves and developing fruits with as nearly as possible optimum conditions for colouration without danger from sunscald and, wherever possible, it should aim at providing these conditions least favourable for the work of injurious insects and diseases.

As described earlier, the trees receive a large part of their training during the first few years for building of their framework. During the later years effects are directed mainly to preserve the form already given to the tree and attention is given to its pruning as distinguished from training. The following are some important factors contributing for a successful training.

Height of head

The distance from the ground at which the main scaffold limbs branch from the trunk is known as head. Trees in which scaffold limbs come out at 76 or 92 cm above the ground level are low headed and when they come out at 122 cm above the ground level are high headed. In older orchards high headed trees was the rule. It was thought that high heading facilitated cultivation and other orchard operations. More recent tendencies have been in the direction of low heads. Because in tropical climates high headed trees are unsuitable, as their exposed trunks are subject to sunscald injury. Also, low headed trees can resist

stormy winds more efficiently and their spraying and harvesting expenses are lessened.

Number and distribution of scaffold limbs

A large percentage of injury resulting from tree breaking when heavily loaded with fruits or subjected to severe wind is indirectly due to sharp crotches resulting from few number of scaffold limbs. A moderate number of scaffold limbs varying from five to eight, makes a tree mechanically strong and open enough to facilitate orchard operations. The scaffold limbs should be well distributed in all directions on the trunk.

Subordinating limbs

In training orchard trees, it is usually better to suppress or subordinate the interior limbs than to attempt their total elimination. Water sprout problem is largely eliminated by subordination. One of the best ways to subordinate and make fruiting branches from these interior limbs is to let them remain with no heading back at the beginning of their second season. After the second seasons' growth, they are headed back to 2-year-old wood. In this way they make little further shoot growth and less difficulty is experienced in keeping them as subordinate fruiting limbs.

Major aspects of pruning

The purpose of pruning at any specific time depends on several factors like age of the plant, its vigour and bearing characters. Until recently pruning recommendations were based on the kind of fruit only, but experience has shown that it is most effective to consider the growth and flowering of specific varieties. Because pronounced differences exist on the growth habits of different varieties of fruit trees. Pruning should be designed to stimulate upright branches, preventing the impingement on each other and formation of an interlocking thicket.

A search through the horticultural literature reveals that there is a great diversity of opinion as to the influence of varying amount of pruning on growth and productiveness. Some have considered heavy pruning as a great stimulant of vegetative growth though it has opposite effect on fruit production. This idea is reflected in the phrase "Prune in the winter for wood". Others have regarded pruning of any kind and more particularly pruning of any amount, as harmful because it has been thought to check the growth.

Effect of pruning on growth

Bedford and Pickering in England and Chandler in America were among the first to demonstrate the fact that although the immediate effect of pruning is to

increase the length of shoots and size of leaves, total growth attained by an unpruned tree is always greater than that of a pruned tree, regardless of the type or amount of pruning. The growth incurred in response to pruning does not compensate for the portion removed by pruning plus the growth which would normally occur on that point. The trunk and branches of unpruned trees show a greater thickness than the pruned trees.

Pruning not only induces the total growth made by the above ground portion but also reduces the total root growth. Experiments have indicated that root growth is dependent upon the satisfactory supply of materials like carbohydrates and phytohormones produced by the leaves. The extent of reduction of total growth following pruning is roughly proportional to the severity of pruning, that is to the number of potential buds and leaves removed. The beneficial effects of pruning, i.e., increased in leaf size and decrease in the exhaustiveness of fruiting, compensate in part for its dwarfing tendency and loss of leaves. These beneficial effects can more nearly equalise a small loss than a heavy one. Hence light pruning is always advised.

Effect of pruning on flower bud formation

Pruning delays differentiation of floral primordia in case of young trees which have not yet flowered. This delay appears to be more or less proportional to the degree of pruning.

Pruning of fruit trees during the first few years of flowering, although produces vigourous shoot growth, rarely entirely inhibits the formation of flowers. The flowering process once initiated is not easily suppressed. Pruning with its stimulation for more shoots and spurs, produces its most beneficial effect on older trees, which have borne for a number of years. The production of fruits has an exhaustive effect and tends towards a reduction in growth of shoots and spurs. And thus the potential flowering points are reduced. Pruning by removing a number of flowers and stimulating a vigorously vegetative type of growth results in new wood which in turn bears flower buds. Pruning by increasing the vigour of the shoots reduces the proportion of flower buds. Furthermore, as the proportion of leaf buds increases, more shoots are produced and yield eventually increases.

Pruning a weak devitalised tree increases its fruitfulness. Observations show that in trees where nitrogen supply is deficient and there is large supply of carbohydrates, pruning tends to increase the differentiation of flowers by increasing the supply of available nitrogen to the growing points.

Effect of pruning on fruit setting

Pruning invariably tends to increase the percentage of flowers which develop into fruits. The elimination of certain growing points indirectly increases the supply of water and nitrogen to the remainder points.

Effect of pruning on yield

The pruning of tree fruits usually results in a reduction in total yield. The effect of pruning upon the yield of marketable fruits is important from the view-point of production. In order to achieve the greatest yield of marketable fruit and most favourable return, proper pruning practices like thinning are advocated. The effect depends on the condition of the tree at the time of pruning. Where the tree is dense and would shade the fruit considerably, a light to moderate pruning tends to increase the marketable yield. On the other hand, if the tree has been well pruned recently, and is already open and making satisfactory growth, even a moderate pruning would reduce the total marketable yield.

Effect of pruning upon size, colour and quality of fruits

Numerous experiments conducted in different places have demonstrated that size, colour and quality of fruits are affected by pruning. The colour of the fruits is unfavourably affected when shading prevents its direct exposure to sunlight. A dense unpruned tree, which has set heavily produces fruits of small size and poor colour as a result of an unfavourable nitrogen-carbohydrate relationship. In both the above cases pruning will be found beneficial. A light rather than a moderate to heavy pruning will produce satisfactory results in most fruit varieties.

4.2 Time and Season of Pruning

The dormant season which comes in between the leaf fall and opening of the buds in spring, has been considered as the preferable period for pruning. Summer pruning is discouraged due to various reasons. When dormant, trees are not barked easily and the worker can easily observe the branches for pruning purpose. In dormant pruning sometimes winter injury is experienced. It is evident that fall or winter pruning of fruit trees may become quite hazardous if low temperature is experienced in the following months. In this case pruning should be delayed until the probability of low temperature is passed.

4.3 Bearing Habit of Fruit Trees

The amount of pruning depends on the bearing habit of the plant. Therefore, one should be thoroughly familiar about the bearing habit of the fruit tree to be pruned. The position of the flower bud is different in different varieties. Buds having the potential to flower are formed either terminally, laterally or adventitiously. The terminal buds may be formed on long or short growth, laterally on

current or past season growth and adventitiously from any point on the trunk or root.

Plants having terminal fruit buds do not possess enormous spreading habit and the trees are rather compact. Similarly, plants possessing flower buds on spurs are more compact than those in which they are borne on long shoots. In this way fruit trees have been classified into six categories in relation to the bearing habits.

Fruit buds borne terminally and giving rise to inflorescence without leaves, e.g., mango.

Fruit buds borne terminally, unfolding to produce leafy shoots which terminate in flower clusters, e.g., apple.

Fruit buds borne terminally, unfolding to produce leafy shoots with flowers or flower clusters, e.g., guava.

Fruit buds borne laterally, containing flower parts only and giving rise to inflorescence without leaves or if leaves present they are reduced in size, e.g., citrus.

Fruit buds borne laterally, unfolding to produce leafy shoots terminating in flower clusters, e.g., grape, cashew.

Fruit buds borne laterally, unfolding to produce leafy shoots with flower clusters in leaf axils, e.g., fig.

4.4 Training and Pruning Practices on Different Fruit Trees

Mango

Training in mango is not so important as other fruit trees, because in nature it assumes a graceful dome shape by shading the trunk perfectly. After planting, the young graft should be allowed to grow unhampered for about 4 years before any pruning is taken up. Branches crowding the centre of the tree should be removed at the end of the fourth year. Weak growth remaining under perpetual shade underneath the main branches should also be cut out. Otherwise, they would remain unfruitful without being exposed to sunlight.

Ordinarily, a mango tree does not have more number of shaded branches which require to be pruned away as undesirable ones. Every healthy branch, if fully exposed to the sunlight, is an asset for fruiting in future. Pruning should not be done unless a branch is diseased or deteriorates due to want of sunlight.

The use of pruning of mango trees is a recent development. According to Rao and Khader (1979), mango trees that are healthy and well grown with lush vegetation but bearing irregularly are necessary to be pruned. Older trees of about 30 to 50 years of age respond well to pruning. In this case the trees are pruned 4 to 4½ months before expected time of flowering. Delayed pruning may upset flowering.

First year pruning in case of over large and densely grown trees consists of removal of a few branches all round the tree and in the centre in such a way so as to open the tree to admit more light and air. The terminal clusters of shoots and young flushes of leaves which are normally 3 to 5 in number should be thinned out to one or two healthy ones. This is done all round the periphery and inside the canopy. Pruning in the subsequent years consists of mere thinning of the terminal whorls of shoots of young flushes. There is no need to prune large branches every year.

Rao and Shanmugavelu (1975) have reported that an experiment carried out at the Department of Horticulture, Tamil Nadu Agricultural University, Coimbatore on Mulgoa mango trees by removing some big branches and thinning out the terminal shoots gave profuse flowering and more yield with quality fruits.

Citrus

Pruning of young citrus trees is confined to the training and development of mechanically strong trees with well spaced scaffold limbs at the early years before fruiting. Generally, no pruning is done after the tree has started bearing fruits.

In the nursery stage, pruning of young citrus plants should begin soon after the scion buds have started growing. Budded citrus plants branch readily and care should be taken to avoid very low headed trees. Thinning out of branches should be done at least once a month during the year following planting and once in two to three months during the first three years. At the early age, trees tending to bear fruits should not be encouraged.

Bearing citrus trees require very little or no pruning. After the crop is harvested, the branches touching the ground should be cut close to the laterals without leaving any stub. All diseased, injured and crossing branches should be removed. Water sprouts should be cut close to their point of origin.

Pervushina (1979) has reported that in lemons pinching above the 12th leaf gave best results as regards yield.

Guava

In nature guava is a bush like tree. In case of grafted plants great vigil is to be given in removing growths from the rootstock. All other branches arising from the trunk should be maintained in the first year. In the second year, at the beginning of the monsoon, the tree should be pruned shaping the framework by keeping well spaced branches. The lowermost branches which happen to come under the shade of the upper stronger ones should be removed to give the tree a clear height. Three to four good, strong and well grown branches radiating from the trunk on all directions should be kept to give the top the shape of a vase. All other branches arising from the trunk should be removed to

give the branches a vigourous growth. In the third year, at the beginning of the monsoon, the twigs growing vertically from the main framework should be removed to allow more sunlight to the centre. Branches growing horizontally outwards and which are fully exposed to the sun should not be pruned as they constitute the productive wood of the tree.

When the main framework is properly built up at the age of four years, the growth from the main limbs choking the centre of the crown should be removed annually along with the water shoots, if any. All dead and diseased branches should be removed regularly.

Litchi

Very little pruning is necessary in litchi after the initial training and building up of the framework. Litchi flowers are borne mostly on new shoots. It is, therefore, necessary to snip old branches for promoting fresh growth. As the fruit are harvested in bunches along with the shoots, the purpose of pruning is somewhat served in this process. If the tree is making too much vegetative growth, pruning of shoots as well as roots is sometimes recommended. Branches should be thinned out to avoid crowding. Further, when the tree becomes very old and produces small sized fruits, heavy pruning may be done to increase the fruit size. However, this process has got limited commercial utility, since the yield is reduced and is not effective for more than a few years.

Sapota

In sapota the fruiting branches as well as the vegetative shoots are so judiciously spaced on the tree by nature and the shape of the crown is so uniform and well balanced all around that little is left for human hand to correct the tree habit by pruning.

No pruning is required for a period of at least 7 to 10 years after the planting. Only the stock growth below the graft union is removed frequently. As sapota is a slow grower, there should not be any haste in pruning the plant till the main branches establish properly.

In case of air layered plants, branches come off very near the ground. These branches are very helpful in thickening the central stem during the first few years. As the tree advances in age these basal branches weigh down to the ground level and almost become unfruitful. Then these branches should be removed to give the tree a height.

Pomegranate

Generally, young pomegranate plants are allowed to grow in a bush form with a number of shoots arising from the ground level. However, it is advisable to train

the young plants to a single stem with a number of well distributed scaffold limbs all around the trunk. In case the tree is to be trained in a bush form, not more than 3 to 4 main branches should be allowed to arise from the ground level. The plant has a tendency to develop suckers and it is very difficult to train the plant to a single stem. For this purpose, the side shoots should be removed at planting time. The tree should be topped at a height of 61-76 cm. No other shoots excepting the main scaffold limbs should be allowed from the ground level. Pruning of selected branches is done to make the plant thick and stocky after six months. The scaffold limbs are again pruned after 6 to 9 months and the desired shape of the tree is formed within 2 to 3 years.

Pomegranate fruits are borne terminally on short branches known as spurs. The spurs arise from mature shoots. These spurs have the capacity to bear fruits for a period of 3 to 4 years and with the advance of age they decline in production. Therefore, the older spurs are to be pruned out to encourage growth of new spurs.

Grape

Proper methods of training and pruning contribute towards higher production of better quality fruits in grape. In warmer parts of India, soon after planting the vine starts making rapid growth and usually attains a height of about one and half meters within six months while it takes longer time in cooler climates. The following training systems are generally practised in grape.

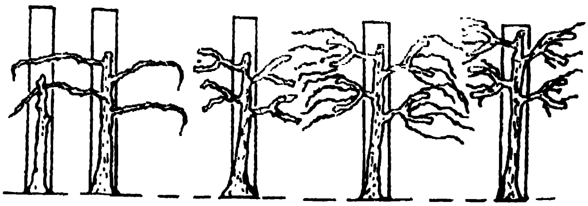
Head System : This is the oldest system of training practised in India. Only one shoot is allowed to grow with the help of a support. It is cut at a height of 92-107 cm in the beginning of July and the cutting back forces the growth of three to four lateral branches which continue growing till the vines become dormant in December.

At the first dormant pruning, the lateral buds are shortened to spur with one or two buds which produce a number of shoots during the second summer and provide suitable arms for the framework. At the second dormant pruning, a sufficient number of arms, growing in different directions, are retained with one or two spurs on each arm for production in the third year.

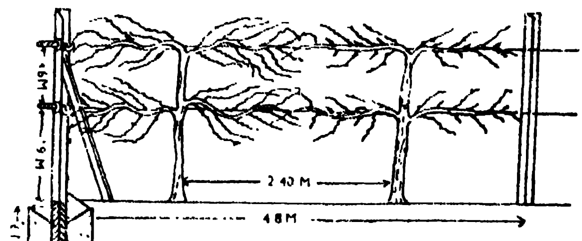
This system of pruning is suitable for varieties which bear fruits on the first few buds of the cane. The method is the cheapest but the yield obtained is low due to the reason that the cropping area is only confined near the head only. The length of the fruiting spurs consist of two to four buds. Al-Rawi and Al-Doori (1977) have reported that grapevines trained on head system and pruned to 8 spurs each with 3, 5 or 7 buds resulted in the increase in the number of sprouting buds and panicles per vine with increasing spur length.

Cordon system : In this method, the vines are trained on horizontal trellis and cordons are developed by pinching the main stem below the wire and trained

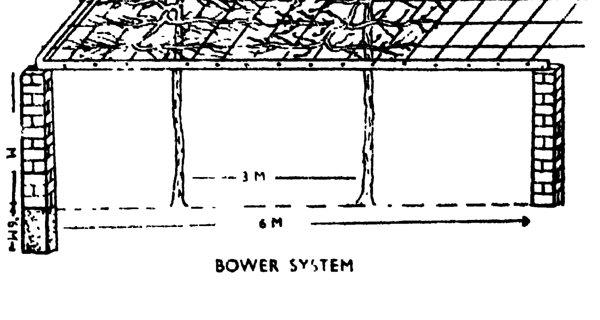
TRAINING OF GRAPEVINES



HEAD SYSTEM



KNIFFIN SYSTEM



BOWER SYSTEM

along the wire. The arms are developed all over the trunk and on each arm short fruiting spurs of two to four buds each are kept at the time of pruning.

In the cordon system, the productive capacity of the uppermost cordon is maximum and the capacity decreases with the successive lower wire resulting from the decreased availability of sunlight. Therefore, the wide top or overhead system of training has been developed by fixing wires at the same level horizontally. The vine is trained by developing two primary arms in opposite direction across the wires fixed at a distance of 60 to 70 cm. Secondary cordons are developed from primary ones and trained along the wires.

The overhead system of training has some advantages like greater spread of the vine and better exposure to sunlight resulting in the maturity of canes, higher production, more uniform colour of the bunch and superior quality fruits.

Kniffin system : This system is an improvement of the cane system, developed by William Kniffin in America. In this system, the arms of the vines are permanent and are tied horizontally with wire trellises, numbering 1 to 3 or more.

A permanent wire-trellis system is at first constructed in the vineyard with strong posts or angle iron poles. They are so apart that 2 vines can be set between 2 poles. The posts or poles are fixed in rows. Kniffin system may be 2-armed or 4-armed. In case of 2-armed Kniffin, G. I. wire should be passed through holes of the poles at a height of 1·5 metre from the ground. In case of 4-armed Kniffin, 2 wires are to be provided, one at 1 metre from the ground and the other at 0·5 metre above it (i.e., 1·5 metre heigh).

The vines are planted just below the wires with stakes. When it touches the wire, in case of 2-armed Kniffin, it is detopped and 2 branches on opposite side are encouraged. In 4-armed Kniffin, when the vine touches the lower wire, 2 arms on each side are retained and the vine is grown till it touches the upper wire. Then it is detopped and 2 branches on each side are retained. The branches or arms are permanent and later become canes. Three-four budded short spurs are maintained on each cane. These give rise to shoots where fruits are borne.

As the arms are horizontal, all shoots get air and light. In 4-armed Kniffin, however, the lower arm is shaded by the upper and yield on this arm is reduced.

Bower system : This system is also known as arbour or pergola system. In this method the canopy can be extended by providing additional wires to the wide top trellis at wide intervals. It has almost all the advantages of the wide top trellis with enhanced fruiting wood.

While the arms grow in length, they put forth side branches. The branches should be pruned annually into short spurs containing two or three buds. Weak branches should be completely removed and strong ones retained on the arms to form spurs spaced about 31 46 cm apart. These spurs grow into new shoots, bear fruits in summer and again cut back in the following year to form new

shoots. The permanent spur heads are built up all along the length of the arms. In the process of pruning from year to year, the fruit bearing wood is pushed ahead gradually. After some years when it is observed that the vigour of the long spur wood is declining, it should be cut back close to the main arm of the vine and new shoots are encouraged.

Bindra and Brar (1979) have reported that out of the six different types of training adopted for grapes, the bower system gave five times as high yield (9·0 kg/plant) as those trained on head system (1·8 kg/plant).

The buds situated on the one-season mature canes are fruitful. In most varieties the buds in the middle section of the cane are highly fruitful while the basal buds are less productive. In other varieties, the basal buds are fruitful. Different varieties are pruned with varying number of buds on the cane.

The pruning time in grape is determined by the weather conditions influencing the growth and development of new shoots and providing ideal conditions for cluster development. In conditions having Mediterranean type of climate the vines undergo dormancy in winter and make new growth during spring. Under such circumstances, pruning is done when the vine is still dormant. The system of pruning once a year is adopted in North India during the cold period. In South India, on account of continuous growth of the vine due to the warm weather prevailing throughout the year, pruning is carried out twice a year. Pruning for fruit is generally carried out in October and the renewed pruning is done in April.

Bukatar and Chikir (1977) have suggested that grapes pruned monthly from November to April gave the best yield and quality fruits during November-December.

Thatai *et al.* (1976) have reported that grape vars. Thompson Seedless, Perlette and Selection-7 trained on the 4-arm Kniffin system, were pruned to 16 canes per vine and the canes were graded as thin, medium, moderate or thick. The highest yields, cluster numbers and average berry weight were obtained from canes of medium thickness. Total soluble solids and reducing sugar contents were highest and acidity was lowest in fruits from canes of medium and moderate thickness.

Grape var. Beauty Seedless, trained on the arbour system was pruned so as to leave sixty 4-bud canes, forty 6-bud canes or thirty 8-bud canes per vine. Yield per vine and berry TSS content were highest with 4-bud or 6-bud canes and the TSS-acidity ratio was highest with 4-bud canes (Saraswat *et al.* 1979).

In an experiment, Bangalore Purple grapes trained on overhead trellis were pruned on 5 or 20 October by retaining one fruiting cane for every 75, 100, 125, 150, 175 or 200 gm of fresh weight of pruned shoots. The percentage of bud burst was highest on the most heavily pruned vines on the earlier date. Yield was greatest (5·06 kg/vine) in 125 gm variant pruned on the earlier date. Grape sugar

content was highest in the 200 gm and 100 gm variants and appreciably higher with all pruning variants carried on the later date.

Ber

In ber, it is desirable to build a strong framework in the early years. Because growth in ber is vigourous and the long slender branches bend badly or break under the heavy load of the fruits which begin at a very early stage. The trunk should have 4-5 well spaced laterals. The budded plants should be staked at the early stage to prevent breakage of the bud union.

Generally, ber fruits are borne in the axil of the leaves on young growing shoots of current season growth. A regular annual pruning is, therefore, necessary to induce good healthy growth and to produce a heavy crop. Thinning out of branches is also desirable to avoid crowding. The best time for pruning ber is during the hot, dry season, when the plants shed their leaves and go to rest. This phase occurs after the harvest of fruits. In North India, pruning is done during mid-May to mid-June.

Results obtained from the work carried out at the Fruit Research Station, Bhatinda, show that the best training system is to obtain a tree with a tree head of one metre from the ground level, possessing an open centre and the main framework consisting of 6 to 8 well distributed branches (Singh and Tomer, 1977).

Pruning of ber at 75 cm shoot length was found most suitable among the pruning levels and has resulted in better response in terms of shoot growth, yield, fruit size and quality (Singh, 1978 ; Singh *et al*, 1978).

Chauhan *et al.* (1981) have suggested that training and pruning of ber during the initial stage of its growth is highly desirable to build up a proper framework and obtain profitable crop in later years. Pruning not only adjusts the growth and bearing but also makes the harvesting operation easier.

Fig

When young, the fig plants have a tendency to put forth new shoots from the base resulting in the production of a large number of shoots springing from close to the ground. This makes the plants bushy which reduces production. Fig plants should be trained to a single stem with well distributed limbs. This facilitates good exposure to sun and increases the yield of quality fruits.

Single stem training is accomplished by removing all side shoots from the lower portion of the plant in the first year of its growth and allowing a single stem to grow straight. This is headed back at 1·25 metres above the ground. Six to eight well distributed shoots are allowed to form the framework. The growth of the tree is balanced by pruning the branches having more vigourous growth and the sides, not producing any shoots and causing imbalance in growth, are made to

produce by notching. All new shoots arising on the main shoots or on the base of the main scaffold limb are pruned off and the new fruit bearing shoots are allowed to arise on the middle or terminal portion of the main limbs.

Generally, the annual pruning consists of heading back the terminal portion of the growth which bore fruits in the previous year. This is done during the beginning of July in western India and during January in northern India, when the plants are in dormant condition.

Sundararaj *et al*, (1969) have reported that pruning of fig by tipping induced more number of new laterals as well as fruits on new shoots over the control.

Custard apple

The custard apple is a slow growing plant having a bush type of growth with a large number of branches. The fruits are borne on old wood as well as on new wood. Pruning can only be done to avoid crowding and promote well spaced branches. Pruning of the old wood is done mostly to induce better branching. Budded or grafted plants are trained to a single stem for better production. Some advocate pruning in custard apple to maintain vigourous growth in order to produce fruits of good quality. Pruning in custard apple should not be done until the buds are ready to start growth in the spring.

Training and pruning are two important interrelated aspects concerning the form, growth and bearing habit of fruit trees and indirectly influence in improving the productiveness and fruit quality. It is said that the endogenous hormonal substances are redistributed in the process of pruning by activating the inactive fruit bearing buds. If left unattended, the trees sometimes acquire unmanageable forms and the interior becomes crowded with unfruitful foliage and makes the tree uneconomic. As a result, further training and pruning becomes cumbersome. It is therefore, imperative to determine the framework of the trees earlier in all cases.

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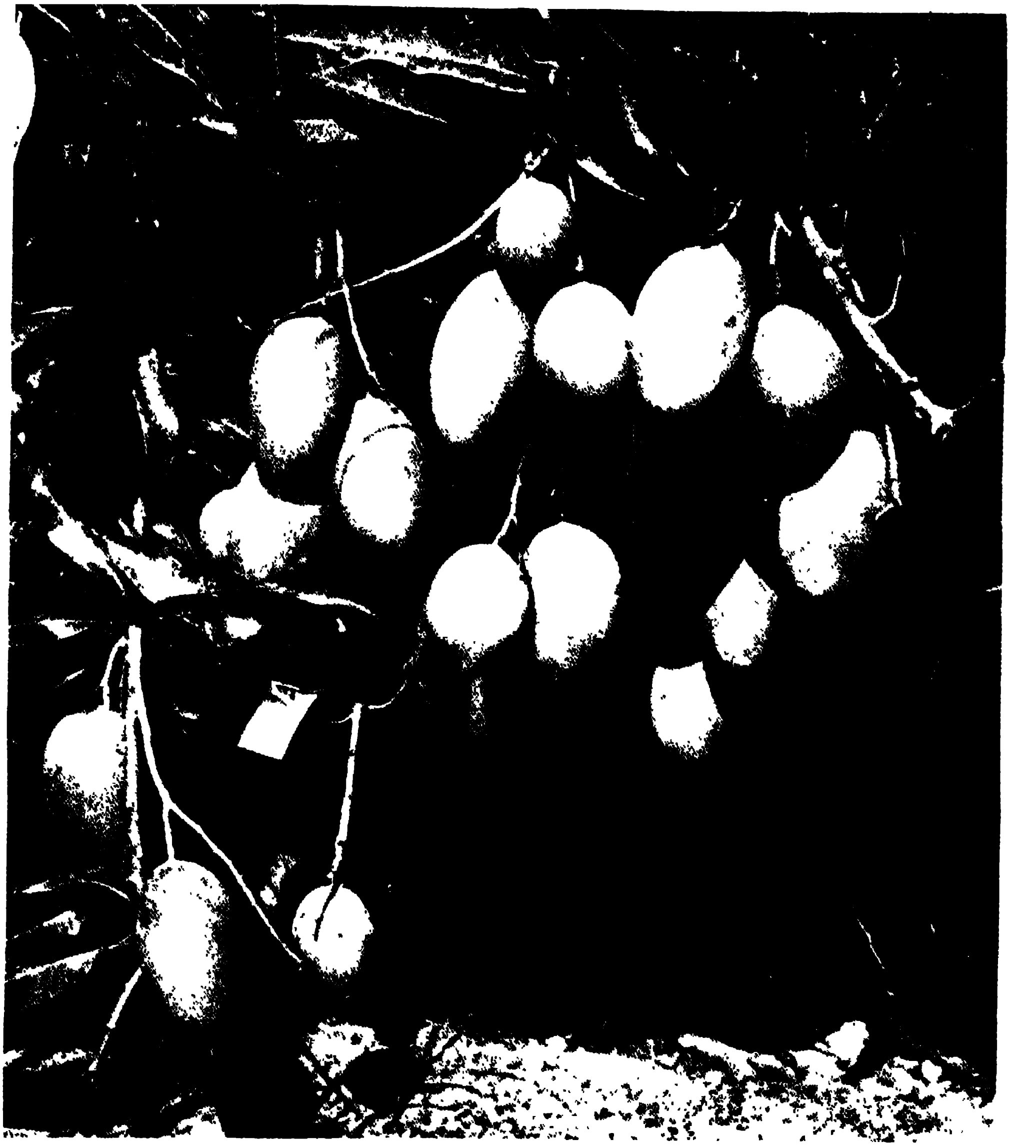
TROPICAL AND SUBTROPICAL FRUITS

Mango trees

Four-year old Amrapali



Fruits of Dashehari

Floral malformation in mango

5

MANGO

P. K. MAJUMDER and D. K. SHARMA

No other fruit, excepting banana, is so closely associated with the history of agriculture, nay, the very history of civilisation itself, as is the mango. Records suggest that it has been in cultivation in the Indian subcontinent for well over 4000 years now (De Candolle, 1904) and has bee , since times immemorial, the favourite of the kings and commoners alike because of its luscious taste and captivating flavour. In India, it is the part and parcel of life, being connected with all phases of life right from birth to death. Ancient Sanskrit scriptures, of various periods, abound in rich references to this plant and the vast uses to which its every part is put.

Legend has it that a mango grove was presented by Amradarika to Lord Budha so that he might use it as a place of repose (Popenoe, 1920). Wayback in 327 B.C., Alexander the Great too had its view on the Indus Valley when he was there on his conquering spree of the world.

It finds mention in the travelogues of ancient travellers beginning from Huan-tsang (632-645 A.D.) who was the first foreigner to bring mango to the notice of the outside world. Ibn Haukal (902-908 A.D.) and Ibn Batuta (1325-1349 A.D.) have written about it (Popenoe, 1920). Amir Khusrau (1330 A.D.), the great Sufi saint and poet, sung its praise during the time of Mohammed Tughalak (1325-1351 A.D.).

In relatively recent times, Nicolo Conti (1419-1444), Ludovici de Varthema (1503-1508), Fryer (1673) and Hamilton (1727) have all mentioned about it (Popenoe, 1920). However, the greatest tribute to this esteemed plant was paid by Emperor Akbar (1556-1605) who established the "Lakh Bagh" (a mango orchard having 100,000 plants) in Darbhanga (Bihar) when large orchards of fruit trees were unknown. In *Ain-e-Akbari* a masterpiece of Persian literature, written by the great chronicler Abul Fazal (1590 A.D.) during the reign of Emperor Akbar, the varieties, cultivation and quality of mangoes have been discussed in detail.

5.1 Composition and Uses

The mango, because of its great utility, occupies a pre-eminent place amongst the fruit crops grown in India and is acknowledged as the King of Fruits of this country. Amir Khusrau (1330 A.D.) has stated (Popenoe, 1920)—

'The mango is the pride of the garden,
the choicest fruit of Hindustan,
Other fruits we are content to eat when ripe,
but the mango is good in all stages of growth'

Young and unripe fruits, because of their acidic taste, are utilised for culinary purposes as well as for preparing pickles, *chutneys* and *amchoor*.

Ripe fruits are utilised in preparing squash, nectar, jam, cereal flakes, custard powder and baby food, mango leather (*ampapar*) and toffee. Besides, fruits of some varieties like Alphonso and Dashehari are sliced and canned for catering to the needs of consumers during the 'off' season.

The various plant parts are put to several other uses, viz., *leaves* : tender ones as vegetable in Java and the Philippines, ash of burnt leaves as a household remedy for burns and scalds, fumes from burning leaves for relief from hiccups and affectations of throat, and leaves are masticated to tone up the gums ; *flowers* : formerly used in preparing an otto (*am attar*), dried flowers have curative properties for treating diarrhoea and chronic dysentry, and also yield a tannin (15 per cent); *bark* : yields mangiferine and tannin (16-20 per cent) useful against diphtheria and rheumatism; *stem* and *trunk* : exude gum and the wood finds use in furniture, flooring, packing boxes, match boxes and splint, brush backs, boats and oar blades (CSIR, 1962).

Constituents of different commercial varieties have not been studied systematically. Comparable parameters have not been utilised and information available is rather inadequate (Jain, 1961 ; Chaudhry and Farooqui, 1969 ; Srinivasan and Shanmugavelu, 1971 ; Kapur, 1974).

The composition, in general, differs with the variety and the stage of maturity. The unripe green mangoes are reported to have 90 per cent moisture, 0·7 per cent protein, 0·1 per cent fat, 8·8 per cent carbohydrates, 0·01 per cent calcium, 0·02 per cent phosphorus, 4·5 mg/100 gm iron, carotene (as vitamin A 150 i.u.), 30 μg/100 gm riboflavin, 3 mg/100 gm ascorbic acid (CSIR, 1962).

Recently, Bhatnagar and Subramanyam (1973) have given a detailed analysis of 10 famous varieties grown in India (Table 1).

Nadkarni (1963) reported that iron, calcium and phosphorus content in 16 varieties ranged between 0·9-3·2 mg, 10-20 mg, and 10-30 mg per cent, respectively.

According to Jain (1961), the sugars in mango comprise sucrose, glucose, fructose and maltose. Others that have been reported to be present are xylose (Sankar, 1963), arabinose (Wali and Hassan, 1965), sedoheptulose and

TABLE 1. CHEMICAL COMPOSITION OF RIPE MANGOES (Bhatnagar and Subramanyam, 1973)

Variety	Per cent fresh weight (Pulp)									
	Moisture	Total soluble solids	pH	Acidity as malic acid	Alchol insoluble residue	Total sugars	Reducing sugars	Vit. C (mg)	Carotenoids μg	
									Total	β-Carotene
Alphonso	78-82	17-20	4·1-4·9	0·14-0·64	1·0-2·5	10·5-18·5	2·5-4·0	50-85	6000-17000	4000-13000
Baneshan	84-86	14-19	4·0-4·8	0·15-0·30	1·5-2·2	10·5-15·5	4·5-7·0	25-35	3500-7500	1500-4000
Pairi	83-86	14-16	4·1-5·0	0·10-0·34	1·0-3·0	11·6-15·6	2·5-5·2	10-25	3500-8400	1000-2500
Totapari	83-85	14-16	4·0-4·2	0·20-0·45	1·0-2·5	11·2-15·4	4·0-5·8	10-20	3000-5500	1800-2500
Neelum	81-83	16-18	4·0-4·2	0·15-0·30	1·0-2·2	11·4-15·5	5·0-7·0	10-25	3500-5400	2000-3500
Mulgoa	80-83	14-20	4·2-5·0	0·10-0·25	2·0-3·5	15·0-16·5	3·2-4·0	20-30	1500-3500	800-2000
Dashehari	76-80	18-22	4·4-5·0	0·20-0·30	1·5-2·2	13·5-16·0	2·5-4·0	25-50	3500-5500	2500-3500
Fazli	78-82	18-20	4·2-4·8	0·10-0·20	1·2-2·0	12·4-15·5	5·0-7·5	75-100	3000-5000	1500-3000
Langra	80-84	18-22	4·2-4·8	0·20-0·35	1·4-2·2	12·1-14·0	2·4-3·5	100-175	5000-8000	2400-5000
Chousa	82-86	18-24	4·0-4·6	0·20-0·35	1·4-2·4	16·0-18·0	2·0-3·0	30-50	3000-5000	1200-3000

mannoheptulose (Ogata *et al.* 1972). Chaudhry and Farooqui (1969) have reported the composition of the varieties Sindhry, Bombay Alphonso, Banganpalli and some seedling mangoes of Sindh province, viz., moisture (79·2-83·0%), total soluble solids (12·9-20·8%), total sugars (10·0-17·3%), non-reducing sugars (7·27-12·35%), ash content (0·49-0·58%), and crude protein (0·38-0·62%) on fresh weight basis. The variety Bombay Alphonso had the highest vitamin C content. Studies of this nature have also been reported from Florida (Soule and Harding, 1956).

Lately, Elahi and Khan (1973) have identified 12 amino acids including the essential ones like alanine, aspartic acid, lysine, leucine, cystine, valine, arginine, phenylalanine and methionine in fruits of 4 mango cultivars grown in Pakistan. These accounted for 10-40 mg/100 gm of edible pulp. The variety Malda had the least acidity and highest amounts of proteins, amino acids and sugars.

According to Jain (1961), small amount of tannin is also present in the flesh (0·16%) and skin (0·105%) which is responsible for astringency.

In a more recent study conducted on 29 varieties of Tamil Nadu, the average fruit weight ranged between 101 gm and 670 gm and the pulp percentage between 53 and 83. The total soluble solids ranged between 11·8 and 26·8 per cent, total sugars from 7·09 to 17·20 per cent and the titrable acidity between 0·14 and 0·58 per cent (Palaniswamy *et al.* 1974). The ascorbic acid content varied from 3·2 to 62·9 mg/100 gm pulp ; smaller fruits having higher amounts than larger ones. According to Siddappa and Bhatia (1954), the ascorbic acid content in Rajapuri varied between 329·0 and 348·5 mg/100 gm in smaller fruitlets weighing between 0·55 and 1·46 gm. However, in larger fruits, weighing 158 gm, it was reduced to as low as 39·1 mg.

Proximate composition of 14 off-season varieties of Tamil Nadu has been reported by Srinivasan and Shanmugavelu (1971).

From the nutritional point of view the mango is a rich source of vitamin A ; almost as rich as butter (Singh, 1960). Also it has fair amounts of vitamin C. The carotenoid pigments, β-carotene (provitamin A), increase with ripening whereas vitamin C registers a sharp fall on ripening (Soule and Hatton, 1955 ; Siddappa and Bhatia, 1954). Singh and Chadha (1961) have reported higher ascorbic acid content in Langra than in Dashehari ; lowest being in Fajri. The concentration fell, although the absolute quantity rose, as the mango fruits matured.

Ghosh (1960) has reported the presence of folic acid (vitamin B) in green mangoes to an extent of 3·6 μg per cent. Vitamin B_1 (thiamine) and vitamin B_2 (riboflavin) range between 35-63 μg and 37-73 μg/100 gm fresh weight, respectively. A more detailed account of the pre- and post-harvest physiology of mango is given by Krishnamurthy and Subramanyam (1973). Sadhu and Bose (1976 ; 1982) studied the chemical composition of fruits of 37 mango varieties from Murshidabad district of West Bengal and reported marked variation in the constituents in different varieties.

5.2 Origin and Distribution

The genus *Mangifera*, which belongs to the family Anacardiaceae, originated in South-East Asia at an early date. According to Mukherjee (1958), the natural spread of the genus is limited to the Indo-Malaysia region, stretching from India to the Philippines and New Guinea in the east. Evidence based on morphological, phytogeographical, cytological, anatomical and pollen studies indicates that the genus had its origin in the continental region of (i) Burma, Thailand, Indo-China and (ii) the Malay Peninsula since these happen to be the main centres of species formation ; the Sunda Islands (Java, Sumatra and Borneo), the Philippines and the Celebes-Timor group forming the secondary centres of development. The highest concentration of *Mangifera* species is reported to be in the Malay Peninsula (19), followed by the Sunda Islands (16) and the Eastern Peninsula (14) ; many of the species being common between them (Mukherjee, 1949).

The genus which has been subdivided into two sections, on the basis of the presence or absence of the disc in the flowers (Mukherjee, 1949), is reported to contain 41 species in all but almost all the edible cultivars of mango belong to the single species *Mangifera indica* Linn which originated in the Indian subcontinent. Occurrence of wild forms of ***M. indica***, allied species ***M. sylvatica*** and ***M. caloneura***, fossil leaf impressions of *M. pentandra* (a species similar to *indica*) and presence of numerous cultivated and wild varieties in India have been cited as some of the major reasons in favour of *Mangifera indica* having originated in the Indo-Burma region through allopolyploidy, possibly amphidiploidy (Mukherjee, 1958). The few other species which contribute edible fruits (though of relatively inferior fruit quality) are *M. caesia*, *M. foetida* and *M. odorata*, which are confined to the Malaysian region.

The mango, though well-known to the people of the Indian subcontinent for several centuries, was virtually unknown to any botanist until 1605 when Carol Clusius first mentioned of it in his writings (Mukherjee, 1949a). Bauhin (1623, 1650), subsequently, referred to it under the names "Mangas" and "Amba". The name *Mangifera* was given for the first time by Bontius in 1658 when he referred to this plant as *arbor Mangifera* (the tree producing mango). Later, it was mentioned in the literature as *Mangifera indica* Ray, *Mangas domestica* Hermann or *Mangas sylvatica* Rheede. Linnaeus also referred to it as ***Mangifera arbor*** in 1747, prior to changing the name to its present form (*Mangifera indica* L) in 1753, in his much quoted book 'Species Plantarum' (Mukherjee, 1949a).

Besides the Indian subcontinent, the mango is now found in several countries of the tropical and subtropical world where it was introduced by Muslim missionaries, Spanish voyagers and Portuguese explorers during the 15th to the 18th century. According to Hayes (1957) it was being cultivated at the head of the Persian Gulf by the 16th century. It was introduced in the Philippines after 1600, in the Moluccas in 1665 and in Yemen in the later part of the 18th century (Burns

and Prayag, 1921). It is also reported that the mango was being grown in England under glass-house conditions as early as 1690 and that the trees at Kew were in fruiting during 1818. In Mexico, it was introduced before 1778 by the Spanish travellers from the Philippines. The Portuguese, who carried mango to South Africa in the 16th century from Goa, were responsible for introducing it in Brazil by 1700 (Popenoe, 1920). It was in cultivation in Barbados in 1742 and in Jamaica in 1782. According to Pope (1929) it was introduced in Hawaii between 1800 to 1820. According to Wester the earliest introductions in Florida were those of the seedlings to the east coast in 1860s and on the west in 1870s (Hayes, 1957). However, it was only in 1889 that the grafted plants were successfully introduced from India by the USDA. It reached Azores in 1865 and Queensland in 1870 (Burns and Prayag, 1921).

Presently, besides India, it is being cultivated in Pakistan, Bangladesh, Burma, Sri Lanka, Thailand, Vietnam, Malaysia, the Philippines, Indonesia, the Fiji Islands, Tropical Australia, Egypt, Israel, Sudan, Somalia, Kenya, Uganda, Tanzania, South Africa, Niger, Nigeria, Zaire, Madagascar, Mauritius, the USA (Florida, Hawaii, Puerto Rico), Venezuela, Mexico, Brazil and the West Indies Islands.

5.3 Species and Varieties

Species

A list of all the species is given below, along with their locations (Mukherjee, 1948):

1.	*M. duperreana* Pierre	...	Cochinchina, Siam
2.	*M. pentandra* Hook. f.	...	Burma, Malaya, Indochina
3.	*M. cochinchinensis* Engl.	...	Cochinchina
4.	*M. lanceolata* Ridl.	...	Malaya
5.	*M. indica* Linn.	...	Tropics of old world
6.	*M. longipes* Griff.	...	Burma, Malaya, Sunda Archipelago, Philippines
7.	*M. caloneura* Kz.	...	Burma, Siam
8.	*M. siamensis* Warbg ex Craib	...	Siam
9.	*M. sylvatica* Roxb.	...	India, Burma, Indochina
10.	*M. oblongifolia* Hook. f.	...	Malacca, Siam, Indochina
11.	*M. minor* Bl.	...	New Guinea, Celebes, Solomon Island
12.	*M. zeylanica* Hook. f.	..	Ceylon
13.	*M. khasiana* Pierre	...	Assam
14.	*M. gracilipes* Hook. f.	...	Malacca

15.	*M. camptosperma* Pierre	...	Burma, Siam, Cochinchina Sumatra
16.	*M. gedebe* Miq.	...	Java
17.	*M. microphylla* Griff. ex Hook. f.	...	Malaya
18.	*M. griffithii* Hook. f.	...	Malaya
19.	*M. sclerophylla* Hook. f.	...	Malaya
20.	*M. merillii* sp. nov.	...	Philippines
21.	*M. beccarii* Ridl.	...	Sarawak
22.	*M. similis* Bl.	...	Sumatra, Java
23.	*M. altissima* Blanco	...	Philippines
24.	*M. rumphii* Pierre	...	Banda Island
25.	*M. philippinensis* sp. nov.	...	Philippines
26.	*M. havilandi* Ridl.	...	Sarawak
27.	*M. rigida* Bl.	...	Sumatra
28.	*M. maingayi* Hook. f.	...	Malaya
29.	*M. longipetiolata* King	...	Malaya
30.	*M. quadrifida* Jack.	...	Malaya, Sumatra, Borneo
31.	*M. spathulaefolia* Bl.	...	Borneo
32.	*M. timorensis* Bl	..	Timor, Banda, Sumatra
33.	*M. monandra* Merr.	...	Philippines
34.	*M. andamanica* King	...	Andaman Island
35.	*M. lagenifera* Griff.	...	Siam, Malaya, Sumatra
36.	*M. macrocarpa* Bl.	...	Malaya, Sunda Archipelago, Anambas Island, Indochina
37.	*M. foetida* Lour.	.	Malaya
38.	*M. odorata* Griff.		Malaya, Philippines
39.	*M. kemanga* Bl.	...	Malaya Peninsula and Archipelago
40.	*M. caesia* Jack.	...	Malay, Sunda Archipelago, Philippines
41.	*M. superba* Hook. f.	.	Malaya

Varieties

Due to the long history of cultivation in this subcontinent, about a thousand varieties of mango are known to exist in India. All these have originated as superior chance seedlings arising from natural crossing or gene mutation. These selections were later maintained true to type through asexual propagation. Almost all these varieties are of monoembryonic type. The polyembryonic types, numbering about a dozen, also exist in India but these are much inferior in fruit size and quality (viz. Bappakai, Chandrakaran, Goa, Kurukkan, Olour, Bellary,

Goa Kasargod, Mazagaon, Nileswar Dwarf and Salem). These are mostly wild and are confined to the southern States, especially on the west coast. Besides these, some polyembryonic varieties have been reported from other countries as well, viz., Cambodiana, Carabao, Cecil, Higgins, Paho, Peach/Turpentine/Apricot, Pico, Sabre, Saigon, Simmonds, Samini and Strawberry (Singh, 1960).

Detailed varietal descriptions of the numerous edible varieties of mango have been given in a number of monographs published from time to time (Maries, 1902 ; Mukherjee, 1948a ; Naik and Gangolly, 1950 ; Singh and Singh, 1956 ; Gangolly *et al*, 1957 ; and Maity *et al*, 1981). However, of these, only a score or so are of commercial significance in the different mango growing regions in the country. In general, the varieties are location-specific and the commercial varieties of one region do not do so well when grown in other areas.

The most popular commercial varieties of different regions are :

Northern region :	Dashehari, Langra, Chausa and Bombay Green ;
Eastern region :	Himsagar, Langra, Fazli, Zardalu, Krishnabhog and Gulabkhas ;
Western region :	Alphonso, Pairi, Kesar, Rajapuri, Malkurad and Jamadar ;
Southern region :	Bangalora, Neelum, Swaranarekha, Pairi (Peter), Banganpalli, Mulgoa and Badami (Alphonso).

Salient characteristics of these varieties are given in the following paragraphs :

Dashehari : This is the most popular variety of northern India because of its attractive appearance, excellent taste and pleasing flavour. It is a mid-season variety, maturing towards the end of June. The fruits are medium in size (4 to 8 per kg), elliptical oblong in shape and have an attractive greenish-yellow colour. It is a good cropper, though biennial in bearing.

Langra : Some people in the North rank it even higher than Dashehari. It is also a mid-meason variety. The fruits are large in size (3 to 4 per kg), oblongish-oval in shape and have lime-green colour. It has excellent sugar/acid blend and a characteristically pleasant flavour. It is a heavy yielder, especially after the age of 15 years. However, this is also biennial in bearing.

Chausa : This is one of the sweetest mangoes, lacking somewhat in acidity. It is a late variety and matures towards the end of July or beginning of August. It starts bearing good crops only after 15-20 years. The fruits are large sized (3 to 4 per kg), almost oblong in shape (with a characteristic sinus) and bright yellow in colour. Its major drawbacks, besides biennial bearing, are its high susceptibility to mango-malformation and very vigorous growth habit.

Bombay green : This is the earliest variety of northern India, maturing during the first half of June. The fruits are medium in size (4 to 6 per kg), ovate in shape and yellowish-green in colour. The taste is good and yield moderate. However, this is also biennial in bearing and highly susceptible to malformation.

Himsagar : This is the most popular commercial variety of West Bengal which mature during the second week of June. The fruits are large in size (4 fruits per kg), oval in shape with yellowish-green colour and somewhat rough skin. The taste is very sweet and the flavour is characteristically pleasant. This is a heavy yielder though biennial in bearing.

Fazli : This is a very late variety (matures late in August) with very large sized fruits (2 fruits per kg). The tree is very vigorous and a medium to heavy cropper, with biennial bearing habit. The fruit quality is relatively poor and its importance lies in its lateness to mature.

Zardalu : This is considered to be a matchless fruit of Bhagalpur (Bihar). It matures towards the end of June. The fruits are medium in size (5 to 6 per kg), oblongish oval in shape (with a slight sinus) and have attractive apricot-yellow colour. The fruit quality is good with a pleasant flavour. It is biennial in bearing.

Krishnabhog : This is a mid-season variety, maturing by middle of July. The fruits are medium to large sized (3-4 fruits per kg), round in shape and have light yellow colour towards the basal end of the fruit. It is a heavy yielder and biennial in habit.

Gulabkhas : The fruit is favoured for its characteristic rose flavour and very sweet taste. The fruits mature in June and are of medium size (5 to 6 per kg), oblong to oblong-oblique in shape (with a well marked to shallow sinus). The fruits are amber-yellow in colour, with reddish blush towards the base and the sides. This is a heavy yielder but biennial in bearing.

Alphonso : This is one of the finest of Indian mangoes and is rated to be the best by many in home and abroad. However, it is also biennial in bearing. It is very specific in its requirements and does best only on the west coast of Maharashtra (Ratnagiri), although it is grown to some extent in the South too. The fruits are very attractive, large sized (3 to 4 per kg) and oval in shape (with a prominent ventral shoulder). The fruits have an attractive pinkish blush towards the basal end. The taste is superb, with an excellent sugar/acid blend. The flavour is captivating. Besides being a table variety, much in demand, it is also a favoured fruit of the processing industry because it retains its characteristic flavour even during processing. It is a medium bearer.

Pairi : This is an excellent variety of western and southern India. The fruit is very attractive, with crimson tinted shoulders on a yellowish-green background. The fruits are medium in size (4 fruits per kg), ovate in shape (with a prominent beak and very slight sinus) and mature around mid-May and June. The bearing is heavy and fruit quality good. It is biennial in habit.

Kesar : The fruits are medium to large sized (3 to 4 per kg), oblong in shape with an attractive light apricot-yellow colour. The taste is very good and

sugar/acid blend is excellent. It is a moderate cropper but biennial in bearing. It is a famous variety of Gujarat.

Rajapuri : This is another famous variety of Gujarat. The fruits are very large sized (2 to 3 per kg), ovate to ovate-oblong in shape and have a bright pinkish blush (on the upper 1/3 of the fruit) on golden-yellow background. The beak is very distinct and sinus is almost absent. The bearing is moderate and the fruits mature by the beginning of June. It is a good quality mango but biennial in habit.

Jamadar : This is another good variety of Gujarat. The fruits are medium sized (5 to 6 per kg), ovate-oblique in shape with apricot-yellow colour. It is a medium cropper but biennial in bearing.

Bangalora : This is one of the most widely cultivated, mid-season variety of southern India. It is a heavy yielder and one of the few regular bearing varieties of mango. The fruits are large sized (2 to 3 per kg) and very typical in shape, i.e., oblong (bottle necked towards the base) with a prominent sinus and beak. The fruits are attractive and have apricot-yellow colour. The skin is thick and keeping quality very good. The fruit quality is relatively inferior but is preferred by the processing industry because of its dependable regular supply.

Neelum : This is yet another heavy yielding and highly regular bearing commercial variety of the South and the fruit quality is relatively more acceptable than Bangalora. The fruits are medium in size (4 to 6 per kg) and the shape is ovate-oblique (roundish). The sinus is somewhat prominent and the beak distinct. The colour is orange-yellow and the taste is somewhat good, with an acidic blend. This variety has a wide adaptability and reaches the northern market late in the season, i.e., end of August to beginning of September Keeping quality is fairly good.

Swaranurekha : This is one of the few table varieties of commerce which have highly coloured fruits of attractive pinkish-red. This appears early in the northern markets, i.e., about the last week of April. The fruit size is medium (4 to 6 per kg) and the shape is ovate-oblong. The flesh is somewhat fibrous and the taste is good, with an acidic blend. The bearing is moderate but biennial.

Banganpalli : This is yet another of the most widely cultivated varieties of the South which is sent to the northern markets very early in the season (i.e., towards the end of April), even when it has not attained proper maturity. Nevertheless, it is good in taste if tasted towards the later half of May. This is also known as Baneshan in the South and Safeda in the North. The fruits are large-sized (2 to 3 per kg) and the colour is very attractive golden-yellow, with a very smooth skin. The shape is obliquely oval. The bearing is moderate and fairly regular.

Mulgoa : This is an excellent late variety of the South but the bearing is rather light and biennial. The fruits size is large (2 to 3 per kg) and shape roundish-oblique, with a sunken basal cavity. The taste is very sweet and flavour delightful. Two strains, red and white, are reported.

5.4 Soil and Climate

Soil

The mango can grow well in all types of soil from alluvial to lateritic, except black cotton soils which are considered to be poor. The only pre-requisites are a deep (2 to 2·5 m) and well drained soil. However, it grows successfully in soft rocky areas of the west coast. Like most other fruit crops, it prefers a slightly acidic soil. It does not do well beyond a pH of 7·5 (Singh, 1960). Soils with an appreciable amount of gravel or *kankar* ($CaCO_3$) in the profile too can grow good mangoes provided they are not very alkaline. Saline and alkaline conditions are not conducive to profitable mango cultivation.

Climate

Although, essentially a tropical fruit, the mango can grow from sea level to an altitude of about 1400 metres provided there is no high humidity, rain or frost during the flowering period. It does well within a temperature range from 24 °C to 27 °C, although it can successfully endure even temperatures as high as 48°C during the period of fruit development and maturity (if facilities for irrigation at regular intervals during this period are available). Higher temperatures during the period of fruit development hasten maturity and improve fruit-size and quality. The limiting factors for its profitable cultivation are low temperatures (freezing) and commonly occurring frosts during the period of flowering.

The amount of rainfall in a given locality is not so important as its intensity and distribution. It can do well in areas having an average rainfall of as low as 25 cm (if irrigation can be provided during the peak requirement period of fruit development) to as high as 250 cm. However, the mango cannot do well in areas which experience frequent rains or high humidity (say, over 80%) during the flowering period. Such conditions are not conducive to a good fruit set and also increase the incidence of serious pests and diseases like powdery mildew and anthracnose. The former is quite common when high humidity is accompanied by low temperatures. These diseases can render the trees completely unproductive, if appropriate and timely measures are not taken to protect the crop. Localities which experience bright sunny days and a relatively low humidity during flowering period are ideal for mango cultivation. Mango being a cross-pollinated crop (pollination is chiefly through various types of insects), the activity of pollinisers is promoted by such ideal conditions (Singh, 1960).

5.5 Area and Production

The mango, in terms of total fruits production on a global basis, is next only to banana and orange. However, in India, it is the major fruit crop. To an estimated total world production (FAO, 1980) of 14,034,000 tonnes in 1979, India's contribution was the highest (9,300,000 tonnes) followed by that of Pakistan (600,000 tonnes), the Philippines (3,38,000 tonnes) and Indonesia (300,000 tonnes).

Although it is the most widely cultivated fruit crop of India, authentic and up-to-date figures regarding its area and production are lacking or are being variously quoted. As per a recent report by the Indian Institute of Foreign Trade, based on season and crop report of the Agriculture and Horticulture Departments of various States (1975-76), the total area under mango was 8,49,700 ha and the total production 7,590,000 tonnes. Surprisingly, even these estimates do not appear to be dependable, since some of the important mango growing States like Maharashtra, Gujarat and Madhya Pradesh are excluded from it.

A compilation by the Crops Division of the Union Ministry of Agriculture for the year 1978-79 shows that the mango, in India, occupies 942,560 ha (42·6%) out of a total area of 2,210,270 ha and the total production is 8,216,510 tonnes. The area under mango has increased from 7,47,500 ha in 1961-62 to the present size but the rate of increase is rather low in comparison to other fruits. According to Mukherjee (1967), the mango occupied about 50% of the total area under fruit crops but by 1978-79 it has come down to 42·6%.

The statewise distribution of area and production under mango is given in Table 2.

TABLE 2. AREA AND PRODUCTION OF MANGO IN INDIA (1978-79)*

States	Area (000 ha)	Production (000 tonnes)	Yield/ha (tonnes)
Uttar Pradesh	313·00	1836·00	5·83
Bihar	127·95	1279·50	10·00
Andhra Pradesh	127·09	1614·09	12·70
Orissa	72·50	924·31	12·74
Kerala	62·53	738·00	11·80
West Bengal	57·00	399·00	7·00
Tamil Nadu	39·17	478·35	12·21
Karnataka	36·21	253·47	7·00
Assam	30·78	47·22	1·53
Madhya Pradesh	23·90	239·00	10·00
Gujarat	22·70	227·00	10·00
Maharashtra	14·80	88·80	6·00
Others (Punjab, Haryana, Tripura, Pondicherry, Dadra and Nagar Haveli and Manipur)	14·93	89·77	6·01
Total	942·56	8214·51	
Average yield/ha			8·67

*Ministry of Agriculture, Crops Division (Crop Unit II), Government of India.

The area under production, figures given in Table 2, does not necessarily pertain to grafted varieties alone. There is considerable area under seedling trees which yield inferior-sized fruits of poor quality. The area under such trees is about 20,000 ha (Singh, 1978).

5.6 Propagation

Root stock

The varieties of mango, as indicated earlier in this chapter, fall into two broad categories (i) monoembryonic and (ii) polyembryonic. Almost all the commercial varieties in the world belong to the former category and do not come true to type from seed and are, therefore, of necessity, to be raised through asexual means. The polyembryonic types are reported to come out true to type from seed since the zygotic embryo is crowded out by the surrounding nucellar embryos and gets degenerated, giving rise to nucellar seedlings only (Sachar and Chopra, 1957). However, in the variety Pico, both nucellar and zygotic embryos develop almost at the same speed (Juliano, 1937) and in such a case the emerging seedlings may be of both types. The nucellar seedlings amongst these can be identified by uniformity in colour of emerging leaves. Polyembryonic types are, by and large, suited only for developing genetically uniform clonal rootstocks which are presently lacking in mango.

For monoembryonic varieties, raising of plants through seeds is restricted only for the purpose of obtaining rootstock seedlings for subsequent grafting.

For rootstock purposes, the seeds must be sown within a week of extraction from the ripe fruits. The mango seeds usually lose their viability within 4-5 weeks (Singh, 1960). The seedlings may be germinated on leaf mould mixed with farm yard manure. The seeds may be placed flat and covered with this mixture. After germination, when the new leaves start turning green (at the age of about 2-3 weeks), the seedlings should be transferred to the nursery bed in two-row system for grafting. The nursery bed should be supplied with adequate amount of well-rotten farm yard manure or leaf mould before transplanting. Subsequently, light and frequent dosages of nitrogenous fertilisers, amounting to 25 kg N/ha may be applied during the year along with irrigation. This will help in inducing quick growth of the seedlings. The seedlings transplanted in the nursery can be grafted in the next season (i.e., July-August).

Techniques of vegetative propagation

Since the mango is a highly cross-pollinated crop there is enormous variation in the seedlings raised even from the fruits of a single tree. The seedling trees

produce heavy crops but the fruit size and quality are, in general, much inferior. Other disadvantages are a long juvenile period (pre-bearing age) and vigorous growth habit, which make adoption of plant protection measures and harvesting of fruits difficult. Above all, the seedling trees do not mature their fruits simultaneously, thereby affecting their marketing. Therefore, for obtaining uniformity in plant performance a given monoembryonic variety will have to be propagated asexually.

The methods of vegetative propagation in mango are known in India since very ancient times, as is indicated by early Sanskrit literature (Singh, 1960). However, according to Popenoe (1920), the technique of inarching was first introduced in India by the European Missionaries in Goa.

Methods of vegetative propagation in mango can be broadly divided into 3 categories, viz., (a) Grafting, (b) Layering and (c)Cutting.

Grafting

This is the most common form in mango and includes inarching and budding. In recent years, more efficient techniques, viz., 'veneer' grafting, 'side grafting' and 'epicotyl' or 'stone' grafting have also been standardised.

Inarching : It has been the most common method of propagating mango varieties and is still followed by the nursery men all over the country. However, it has the following major disadvantages :

(i) It is a cumbersome method since the rootstock seedlings have to be carried to the mother plant for grafting.

(ii) It is laborious and time consuming since 'machans' (raised structures) are to be fabricated around the mother tree for placing the rootstock seedlings for grafting.

(iii) The inarched plants have to be irrigated and looked after for at least 2 to 3 months at various odd places around the tree.

(iv) It is uneconomical since only one plant can be obtained by grafting a long scion-shoot.

(v) Inarched plants usually get pot-bound and hence mortality on transplanting is rather high, the ideal age of potted seedlings for grafting being about an year.

Veneer grafting and side grafting : These are by far the best methods of propagation for mango since these are easier, more economical, give a higher degree of success and are ideal for establishing *in situ* orchards. Besides, being detached methods of grafting (unlike inarching), these techniques can be successfully utilised for preparing plants anywhere since the scion-sticks can keep well for 5-6 days, during which these can be transported to any place for grafting (Majumder *et al*, 1972a). Also, these are ideal methods for converting old and inferior seedling trees into productive ones of a desired superior variety through

top-working. The only difference between these two methods is that in veneer grafting (Mukherjee and Majumder 1961, 1964) the vertical flap of the rootstock bark is completely removed while grafting, whereas in the other (Kashyap *et al*, 1972) this flap is retained and tied over the scion. In veneer grafting only one side of the scion is sliced away in a sloping manner, whereas in side grafting, the scion is sliced on both sides of the lower portion in the form of a wedge.

Proper selection and preparation of scion are of utmost importance in both these methods. The scion should be of matching thickness with the stock, preferably a terminal non-flowered shoot of 3 to 4 months' maturity. Selected scions are defoliated on the mother plant about 7 to 10 days prior to detaching, keeping a part of the petiole intact on the selected terminal shoot. This helps in forcing the buds to swell and in increasing the percentage success in grafting. This method can be successfully employed during March to September in northern India.

Epicotyl/stone grafting : This has been standardised relatively recently (Mukherjee *et al*, 1966 ; Bhan *et al*, 1969 ; Majumder and Rathore, 1970) and holds great promise for multiplying plants in larger number and in lesser time. The seeds are placed on a sand bed and covered with 5·0-7·5 cm thick layer of leaf mould for germination. Germinated seedlings of 8 to 15 days' age are taken out and grafted indoor by beheading the seedlings about 5.0 cm above the stone and inserting thewedge shaped scion in the vertical split in the beheaded rootstock. Polythene tape (200 gauge thickness) is utilised for tying the graft. Immediately thereafter, the grafts are planted in polythene bags filled with soil and farm yard manure mixture (1 : 1). The grafts are watered and kept in semi-shade condition to avoid damaging effects of sun and rain.

Budding : This is the most economical method but has not given uniformly good success in different agroclimatic regions ; percentage success varying considerably in various areas. This is best suited to areas where general atmospheric humidity remains high. This is certainly not the method for hot and dry regions. The best time of budding is reported to be early spring although in some parts of the country it can be done during the early part of the rainy season, i.e., April to June (Singh, 1960). In southern parts of the country, August-September is an ideal period since the weather is relatively cooler also (Gandhi, 1955). The methods most commonly employed are 'Patch', 'Shield' and 'Forkert' budding (Singh, 1960).

Layering

This method of propagation, though commercially applicable under high atmospheric humidity in crops like litchi, is of little utility in propagating mango varieties. Nevertheless, this does hold promise for developing clonal rootstocks for mango. It is practised during the rainy season and leads to own-rooted plants. This is slightly different from rooting of cuttings and the main difference is

that the layering is done for inducing roots when the shoot is still attached to the mother plant.

This method, as practised in mango, is broadly of three types—air-layering or 'Gootee', pot-layering and stooling.

Air-layering : It consists of removing a ring of bark of about 2·5 cm width from around the shoot to be rooted and covering it with a rooting medium. Until recently, the ringed portion was covered with moistened soil and farm yard manure mixture. Later, sphagnum moss came to be used instead. After covering the ringed portion with a wrapping material (gunny sack piece or a polythene sheet) one had to wait for the appearance of roots, which usually took 2 to 2½ months. However, this method was not found to be applicable commercially because of poor establishment in the nursery. After the discovery of plant growth regulators (root promoters like IBA and NAA), the percentage success in rooting increased considerably (Thakurta and Dutt, 1941 ; Singh and Teaotia, 1951 ; Singh, 1954). Marked improvement in root formation in air-layers of important mango varieties was reported by Sen *et al*, (1961) by using IBA. Subsequently, rooting of air-layers was further improved by etiolation treatment followed by application of IBA and NAA (Mukherjee and Bid, 1965).

Pot-layering : This is somewhat more advantageous than the air-layering in the sense that the transplanting shock is much reduced because the shoot to be rooted is bent and buried in a pot containing soil and farm yard manure mixture. Ringing and IBA application are the same as in the earlier type (Singh, 1960).

Stooling : This is an improvement over ground layering (Singh, 1960) and has been standardised for mango (Majumder and Mukherjee, 1961a. ; Mukherjee and Majumder, 1963). This method is easier and more economical since larger number of rooted shoots can be obtained (4 to 6) from a single plant (stool). However, before establishing the stool-bed one has to prepare the mother plants through air-layering or through rooting of cuttings. Afterwards these are planted in nursery bed at a spacing of 75 cm × 50 cm. After about 2 years' growth the main stem of the mother plant (stool) is headed back near the ground (about 10 to 12 cm above). This results in the emergence of several shoots on each plant (stool), from just below the cut end. All, but the most vigorous shoot, are ringed in the usual manner and IBA (5000 ppm) in lanolin is applied on the ringed portion for about a week before earthing up. The treated shoots get rooted in about 4 to 6 weeks and are, then separated from the mother stool. The same plants can be utilised for about 10 years to obtain genetically uniform rooted plants of a given clone (Majumder *et al*, 1972).

Cutting

This method is of great significance for developing clonal rootstocks which are lacking in mango. However, in general, it is rather difficult-to-root hardwood

cuttings. This was tried by some early workers but did not yield any encouraging results. It was first attempted by Thakurta and Dutt (1941) using 2-3 year-old juvenile plants with 3 per cent IAA in lanolin. Singh and Teaotia (1951) reported that cuttings from bearing trees do not root even with the help of growth regulators.

Mukherjee *et al*, (1965, 1967) achieved a major breakthrough by obtaining 50 per cent success from cuttings prepared from 10-year-old trees. This could be possible by invigoration and etiolation treatments. The cuttings made from the basal branches of the tree gave better success than those prepared from the middle or top portion of the plant (Mukherjee *et al*, 1966a).

Intermittent mist has also been found to be very helpful in rooting of hard-wood cuttings. This has given a success of as high as 80 per cent when these were ringed and treated with IBA (Sen *et al*, 1968). The changes in metabolites, levels of endogenous promoters and inhibitors and ethylene during regeneration of roots in mango cuttings taken from seedlings as well as from mature trees by treatment with IBA was reported by Dhua *et al*, (1982).

Another simple technique, devised recently at the IARI (Reddy and Majumder, 1975), will facilitate rooting of cuttings through 'bottom heat'. The device employed consists of a double tin container, the outer one being 70 cm in height and 46 cm in diameter and an inner jacket having a height of 68 cm and a diameter of 44 cm. The space between inner jacket and outer container is packed with glass wool for heat insulation. Another container which fits into the inner jacket (also constructed from the same material measuring 35 cm in height) and having two electric bulbs of 40 watt each at the bottom end—in between the vacant space in two containers, is fitted into the double container mentioned above. This container is then filled with the rooting media (1 part sphagnum moss : 1 part sand : 1 part grit) and the nonleafy hardwood cuttings are planted in it. The temperature is maintained at about 30°C±2° through a thermostat which controls the heating bulbs. The cuttings root in about a month and the success is as high as 97 per cent.

Stock-scion relationship

Since rootstocks for different varieties have not yet been standardised, it is not possible to indicate the precise relationship. However, in mango, all plants of a given variety are known to have the same characteristic canopy shape of the variety, despite the rootstocks being of seedling origin and hence highly variable. For instance, trees of Dashehari, Langra or Chausa retain their characteristic canopy shape and can be identified from a distance. Nevertheless, it is quite likely that, as in some other tree fruits, stock may be having some influence on other characters like vigour, bearing capacity, fruit size and quality.

Rootstock work in mango is still in its embryonic stage. Nevertheless, a good beginning has been made at the IARI to achieve a major breakthrough, by

working out pre-selection criteria for dwarfness so that in future it might become easier to go in for high density orcharding in mango. The criteria which have shown good correlation with dwarfness are—(i) high bark percentage, (ii) small area of xylem vessels and (iii) lower stomatal density (Majumder *et al*, 1972, 1981). The varieties Totapari Red Small and Olour appear to be promising for developing dwarfing clonal rootstocks.

Studies conducted elsewhere indicate that the varieties Kalapady (Sen, 1939), Olour and Ambalavi (Jauhari *et al*, 1972), Vellai Collumban (Singh and Singh, 1976), and Belkhas and Parikhas (Mukherjee and Das, 1976) too have potential for imparting dwarfness.

5.7 Cultivation

Once one has taken into consideration the climatic and soil requirements of mango, the next step is to lay out the orchard. The land may be prepared by usual ploughing, harrowing and levelling. There should be a gentle slope to facilitate proper irrigation and prompt drainage to avoid the harmful effects of water stagnation during rains.

System of planting

The various systems in vogue are the (i) Square, (ii) Rectangular, (iii) Quincunx, (iv) Hexagonal and (v) Contour (Singh, 1960). Of these, the square system is the most popular in mango. The planting distance will vary with the vigour of the variety and the location, ranging between 10 and 12 metres.

Preparation of pits, planting and protection of plants

After marking the places for the plants, pits of 90 cm × 90 cm × 90 cm are usually dug out during summer months. This process should, preferably, be executed, utilising a 'planting board' so that the precise location of the plant in the middle of the pit remains undisturbed. Digging of pits is very essential for somewhat heavy type of soil or soils with a shallow hard pan. While digging, it is necessary to keep the top soil and the subsoil separately in two heaps near each pit for about 2 to 4 weeks. This helps in exposing harmful soil organisms to weathering agencies, providing better aeration in the future rooting zone and in making provision for the nutritional requirements for the healthy development of the plant. However, exposing soils (for long in summer) which have poor organic matter content is not advisable since it may result in its further losses due to oxidation. While filling back the dug pits, well decomposed organic matter is mixed with the top soil and the subsoil separately (in equal proportion) and the top soil mixture is filled first at the bottom of the pit. Elaborate manuring

of pits has also been suggested by some workers. Burns and Prayag (1921) recommended mixing of 100 lb (45·4 kg) of well rotten manure, 5 lb (2·27 kg) of bone meal and 10 lb (4·54 kg) of wood ash with the soil of the pit. Allan recommended mixing of smaller amounts, i.e., 30 to 40 lb (13·62-18·16 kg) of manure, 6 lb (2·72 kg) of bone meal and 6 lb (2·72 kg) of wood ash in the lower 2' (60 cm) of the pit, whereas for the upper 1' (30 cm) he suggested mixing of 10 lb (4·54 kg) of manure, 2 to 3 lb (908 gm to 1·36 kg) of bone meal and 2 lb (908 gm) of neem cake (c.f. Hayes, 1957). These workers recommended that the dosages might be increased each year for several years. However, one cannot entirely be guided by such suggestions since these are not based on scientific experimentation.

In areas where termites are a problem, it is advisable to mix Aldrin dust in the pit mixture @ 150 gm/pit.

Planting is done during the rainy season when the soil in the pits has already settled (following a shower or two). While planting one should be careful that the earth ball does not break and the graft union remains well above the ground level. The planting should preferably be done during cloudy weather and in the evening. The plants should be irrigated immediately after planting. These should be attended to especially in the initial first week or so to rectify any defects like sinking of soil, leaning of plants, etc.

In the initial 2-3 years, it is advisable to protect the plants against low temperature injury by covering the plants with some sort of cover, leaving the eastern side open for entrance of light. Building up slow fires, which emit smoke, and resorting to flood irrigation may also be essential to ward off the ill effects of frost.

Irrigation

Water requirements for tree fruits, in general, have not been worked out so far. The recommendations are mostly based on personal whims and are, hence, arbitrary. One will have to modify these according to the soil and climatic conditions prevailing in an area. Nevertheless, it does sound sensible that in the pre-bearing age (say up to 2 years) the plants must be irrigated more frequently. However, one should remember that the amount and timing will vary with the climatic conditions (varying seasonal changes) and the physical properties of the soil. For instance, heavier soils will require more water but at longer intervals as compared to lighter soil which will require less water at quicker intervals. The interval between two irrigations may be from 3-4 days in summer to once a fortnight during winter.

In the case of bearing trees irrigation at regular intervals (10 to 15 days) is an absolute necessity during the fruit development period ; beginning from fruit-set stage to full development stage. This is helpful in improving fruit size

and in reducing fruit drop. However, for obtaining good flowering one must stop irrigation at least 2 to 3 months before the flowering period. Irrigation during this period is likely to promote vegetative growth, which will be detrimental to flowering.

Manuring and fertilisation

This is another vital aspect which has not merited the requisite attention and the recommendations made in the literature can, at the most, serve a limited purpose (Sen and Roy, 1945 ; Sen *et al*, 1947 ; Roy *et al*, 1951 ; Mallik and De, 1952 ; Singh, 1962).

Non-bearing age : The requirements of an year-old plant can reportedly be met by 75 gm of nitrogen, 110 gm of P_2O_5 and 55 gm of K_2O (Singh, 1967). Forty to eighty per cent of nitrogen should be in the form of organic manure. These dosages need to be increased by the same amount each year. Another estimate suggests that an year-old plant should be supplied with a mixture of 10 kg farm yard manure, 2·5 kg bone meal and 1 kg of sulphate of potash (Singh, 1978). These quantities should be increased every year by 5 kg of farm yard manure, 0·5 kg of bone meal and 0·4 kg of sulphate of potash till the age of 10 years. The Central Mango Research Station at Rehmankhera has recommended that during the non-bearing stage the plants should be supplied with 73 gm of nitrogen, 18 gm of P_2O_5 and 68 gm of K_2O/tree per year of age.

Though a consensus on manurial requirements during the non-bearing age is difficult to reach because of inconsistencies in recommendations, the fact remains that nitrogen application is of vital importance for inducing optimum vegetative growth in this critical phase of the plant. In this connection it would be worthwhile to apply some amounts of P and K also since the former is required to cope up with the high respiration rates and for translocation of carbohydrates and. the latter. is essential for photosynthesis (Singh, 1967). Application of nitrogen increases growth, more especially if P and K are also added. An excessive application of nitrogen would lead to K deficiency, unless potash is also supplied to the plant (Roy *et al*, 1951 ; Mallik and De, 1952).

Bearing trees : The recommendations made in the literature are, by and large, centred around the observations made at Sabour by Roy *et al* (1951) on the basis of pot culture experiments. As per this study, a bearing tree requires 1·6 lb (726 gm) of nitrogen, 0·4 lb (182 gm) of P_2O_5 and 1·5 lb (671 gm) of K_2O. It is also recommended that in the year of heavy fruiting ('on' year) the nitrogen application may be doubled. These requirements can be met by applying 200 lb (90·8 kg) of farm yard manure, 4 lb (1·82 kg) of castor cake, 10 lb (4·54 kg) of bone meal, 2 lb (908 gm) of ammonium sulphate and 30 lb (13·62 kg) of wood ash.

Another study, based on loss of nutrients through crop removal in the var. Dashehari, conducted at Saharanpur (Singh, 1962), indicated that applying 20 kg

of N, P, K and Mg fertilisers (in the ratio of 6 : 3 : 10 : 3) would compensate for their losses due to the removal of 1000 kg of fruit. However, experience shows that these amounts are rather too low and until more elaborate and systematic investigations are conducted in different regions, it would be better to base ones manurial schedule on the work done at Sabour. Application of 1 kg N, 0·5 kg P_2O_5 and 1 kg K_2O and 3 per cent urea as foliar spray per year after pruning resulted in marked improvement in fruit yield in 60-year-old declined Fazli tree (Bose *et al.* in press).

Micro-nutrients

Deficiency of these elements is, generally, not encountered although in Florida symptoms of Fe, Mn, Zn, B and Cu deficiency have been observed in the varieties Haden and Zill (Smith and Scudder, 1951). Zinc deficiency (in the form of little leaf) was first reported from Florida (Lynch and Ruehle, 1940) and subsequently from Israel also (Oppenheimer and Gazit, 1961). Deficiency of Zn is not reported to affect yield and can be corrected by zinc sulphate sprays.

Time of application : Plants in non-bearing stage can be supplied with fertilisers in several split dosages during summer and rainy season. This helps in avoiding losses of nutrients through leaching since the root system of young plants is not so elaborate as to make use of the entire quantity applied at one time.

However, for bearing trees, the time of application is related to the time of production of vegetative flush and that of the fruit bud differentiation (Singh, 1960). The main idea to be kept in mind is the time at which the different major nutrients will be most needed by the tree to show its optimum performance. In this connection, the timing will, therefore, be influenced by the nature of the manures or fertilisers also, i.e., whether a given type becomes quickly available to the plant in a short span of time or its availability is slower and spread over a longer duration.

For bearing trees it is advisable to apply full quantity of nitrogenous fertiliser, along with half of phosphorus and half of potash just after harvesting the fruits. Remaining quantities of these two fertilisers may be applied during October, with the last irrigation. This is also an appropriate time for applying of organic manures which release the nutrients slowly.

Mode of application : A precise knowledge of the rooting pattern and the root system is an essential prerequisite for scientific application of manures and fertilisers. Systematic studies on this aspect are still lacking. Nevertheless, it is well known that the mango has a long tap root ; sometimes extending down to the depth of water table up to a depth of even 5.5 m (Stephens, 1949).

A study conducted in Pakistan has shown that the effective root-system of an eighteen-year-old mango tree is confined to a depth of 1·2 m and extends up to 1·8 m from the trunk (Musahib-ud-din, 1960). However, at Saharanpur, the

roots of a 30 year-old seedling tree were found to extend to a distance of 7·5 m on one side of the tree (Singh, 1960).

Studies conducted at the IARI through radio-isotopes (^{32}P) indicate that the feeding roots of a full grown mango tree are located between 1·20 m and 2·40 m from the trunk (Singh, 1978). Most of the feeding roots were observed at three depths, i. e., 30, 60 and 90 cm ; the maximum density being within 30 cm. These observations suggest that for better utilisation by the plant fertiliser applications for such bearing trees should be made only within this area.

Intercropping and cover-cropping

Intercropping : In tree fruits it is considered advisable to grow some crops in the initial years of orchard establishment when there is no income from the primary crop. Another advantage is that the vacant land, if left unutilised, will lead to build up of weeds, depletion of nutrients, and harbouring of serious pests and diseases. Also, intercropping helps in reducing nutrient losses through leaching.

An intercrop should, preferably, be some short duration shallow-rooted vegetable crop or even a quick growing fruit plant with a short juvenile period. Amongst vegetable crops, one may profitably go in for onion, tomato, radish, carrot, beans, cauliflower, cabbage and 'palak'. Heavy feeders like colocasia, ginger, turmeric and grain crops should be avoided altogether. Amongst fruit crops (as intercrops) one may grow phalsa, papaya, guava, low-chilling peaches, strawberry and pineapple.

In general, an intercrop must be plantéd well away from the mango plants and their requirements for moisture and nutrients must be met separately and must not clash with those for mango. With the increasing age of mango plants, the area under intercrops should be progressively decreased to avoid competition. One must be vigilant to adopt timely and effective control measures against pests and diseases affecting the intercrop.

Cover-cropping : Besides the intercrops one may also grow some crops like- sunnhemp (in light soils) or 'dhaincha' (for heavy soils) to protect the orchard soil from erosion and also for enriching the soil fertility. These crops are sown with the beginning of the rainy season and are ploughed down before the stems become woody (towards the end of monsoon). One can choose any other crop like cowpea, pea, berseem, 'mung', 'urid' and 'guar'.

Pruning and training

The mango, being an evergreen plant, hardly needs any pruning. The only pruning that it requires is periodic removal of the dead and diseased branches, as and when one notices them. Training, however, is an essential practice in the initial 2-3 years. This is done with a view to providing a good framework for the

future so that the branches are spaced properly and these do not break with the crop load at the bearing stage. The branches are not encouraged too low on the trunk or too high from the ground level.

Interculture

Maintenance of good sanitary conditions is a must for keeping an orchard in healthy and disease-free condition. In the initial years of establishment, when one has to go in for intercrops or cover-crops, one normally gives preparatory tillage to the plots. However, when the mango trees are full grown, and inter-cropping is neither feasible nor desirable, it is necessary to plough up the soil to a shallow depth at least twice a year, i.e., in June and October. Also, the tree basins must be kept free of weeds at all times of the year by shallow hoeing and weeding.

5.8 Flowering, Pollination and Fruitset

As indicated earlier, almost all the varieties of mango are prone to the phenomenon of biennial bearing and a certain amount of shoot maturity is an essential prerequisite to their flowering. However, in the case of regular bearing varieties this is not so and shoots of any size or maturity are capable of flowering and fruiting (Singh, 1959: Singh *et al*, 1962). Flowering time is, therefore, closely linked with the time of flower bud differentiation which varies with the variety and the area where it is grown.

Flower bud differentiation

The flower bud differentiation in most cases occurs between October to December (Singh, 1960), although Musahib-ud-din and Dinsa (1946) reported it to occur in August which is rather too early in the light of the present state of knowledge. In the case of 'Baramasi' group of varieties, variously designated as Baramasi/Dophala/Tephala, which has an erratic habit of producing some crop (though usually of inferior size and quality) around the year, the flower bud differentiation is not linked with the time of shoot emergence or maturity and the flower bud differentiation usually occurs during May-June and September-October (Singh, 1978).

Flowering

The flowering in mango takes place as early as November-December in Rayalasema area of Andhra Pradesh (Gandhi, 1955), February to March in the northern India (Singh, 1960) and slightly earlier (January-February) in the eastern parts of the country.

Since the flowering process is entirely dependent on climatic conditions prevailing in an area, at some locations like Kanyakumari, which have a very specific micro-climate, even varieties like Neelum, Bangalora and Rumani have a tendency to flower in the off-season and the fruits usually mature during January-February, much earlier than anywhere else in India.

Duration of flowering

The flowering period in mango is usually of a short duration of 2 to 3 weeks; low temperatures may extend it, whereas higher temperatures may shorten it. The mango tree does not flower simultaneously in all directions and, at least, two distinct flushes are noticed. The panicles located on the eastern and south-eastern aspects of the tree are the first to flower.

Sex-ratio

The mango inflorescence or panicle bears mainly two types of flowers male and perfect, though neutral flowers are also encountered occasionally. The number of flowers per panicle varies between 1000 to 6000, depending upon the variety (Mukherjee, 1953). However, according to Bijhouwer (1937) it ranges from 788 to 9020 in Alphonso and seven varieties of Java. The percentage of perfect flowers varies between 0·74 per cent in Rumani to 69·8 per cent in Langra (Singh, 1954). It is reported to be 30·6 per cent in Dashehari (Singh, 1954); 42·9 per cent in Chausa (Randhawa and Damodaran, 1961); 9·20 per cent in Bombay Green and 14·9 per cent in Fazli (Mallik, 1957); 8·40 per cent in Himsagar (Majumder and Mukherjee, 1961); 16·41 to 55·7 per cent in Neelum, 6·61 to 21·0 per cent in Bangalora, 3·67 per cent in Baneshan, 5·67 to 8·44 per cent in Mulgoa and 32·49 per cent in Pairi (Bhujanga Rao and Rangacharlu, 1958).

Sex-variation

The sex-ratio in different varieties is greatly influenced by the environment in which these are grown. Even the same variety behaves differently in different localities. This is illustrated by the fact that some of the south Indian varieties of mango like Neelum, Baneshan, Allumpur, Janardhan Pasand and Willard when grown under North Indian conditions have significantly lower proportion of perfect flowers than under South Indian conditions (Singh *et al*, 1965).

Investigations into the causes of this phenomenon revealed that lower temperatures during the period of panicle development result in an increased proportion of male flowers. The early flush, emerging on the eastern and south-eastern aspects of the tree, is therefore found to have a higher sex-ratio (i. e., lower proportion of perfect flowers in comparison to male flowers). On the other hand, late emerged panicles, which experience relatively warmer environment

during their developmental period, have a higher percentage of perfect flowers (Majumder and Mukherjee. 1961 ; Singh *et al*, 1966). Also, it has been observed that the panicles located in the inner portions of the tree have a significantly higher proportion of perfect flowers than the panicles located on the periphery. The proportion of perfect flowers varies in different portions of the same panicles ; the highest being in the terminal portion. It is also reported to improve with the age of the plant.

The proportion of perfect flowers in a variety becomes detrimental to optimum fruit set only when it drops down to as low as 1 per cent or so. However, the situation can be improved significantly by exogenous application of NAA (200 ppm) at the time of flower bud initiation (Singh *et al*, 1965).

The initial fruit set in mango is directly related to the proportion of perfect flowers but the final retention has nothing to do with it and appears to be a varietal characteristic. For instance, the initial fruit set in the variety Langra is very high and impressive but the ultimate retention per panicle is better in the var.Dashehari which has a relatively lower proportion of perfect flowers.

Pollination and fruit set

The mango is a highly cross-pollinated crop. Pollination is through insects, though earlier it had been suggested that it can take place through gravity and wind (Maheshwari, 1934).

The insects reported (Singh. 1954a) to be responsible for effecting pollination are *Musca domestica* (the common housefly). *Melipona* sp. (a small Dipterous fly) and *Syrphidae* sp. (a kind of hoverfly).

In nature, more than 50 per cent of the flowers do not receive any pollen grain. The number of pollen grains per pollinated flower, in nature, is also rather too low ; less than 3 per flower (Wagle, 1929 ; Sharma and Singh, 1970).

Some earlier workers had suggested that possibility of self-pollination in some varieties cannot be ruled out (Wagle, 1929 ; Bijhouwer, 1937 ; Dijkman and Soule. 1951). However, bagging of panicles did not result in fruit set (Musahib-ud-din and Dinsa, 1946 ; Singh, 1954a). Nevertheless, studies have shown that the mango ovary is capable of attaining a substantial increase in size without any stimulus of pollination (Naik and Rao, 1943 ; Marloth, 1947 ; Singh, 1954a). Later studies have shown that unpollinated flowers of the var. Dashehari could continue on the panicles upto the 13th day after anthesis ; the mean size of the ovary and ovule at that stage being about 2½ times more than that at anthesis (Sharma and Singh, 1970). Certainly, this cannot be considered as the fruit set stage.

Although some workers (Dijkman and Soule, 1951) had suspected the existence of self-sterility in mango, it was not known until 1962 when Singh, Majumder and Sharma reported its occurrence for the first time in the variety

Dashehari. Subsequently, detailed studies were conducted in the four popular varieties of Northern India (viz. Dashehari, Langra, Chausa and Bombay Green) and these were all found to be self-incompatible (Mukherjee *et al*, 1968 ; Sharma and Singh. 1970a). The type of self-incompatibility observed in mango was of an uncommon type (Sharma and Singh, 1970a) ; thus far reported only in the case of *Theobroma cacao* (Knight and Rogers, 1955 ; Cope, 1962).

The initial fruit set, following self-pollination in the four varieties was rather negligible (0 to 1·68 per cent), as compared to that after cross-pollination (6·40 to 23·40 per cent), from the 15th day after pollination the selfed fruitlets were invariably the smaller and majority of these dropped down within 4 weeks of pollination. None of the selfed fruitlets reached even the half-grown stage (Sharma and Singh, 1970a).

An analysis of the causes of this phenomenon revealed that the processes culminating in the fertilisation of the ovule were the same as after compatible cross-pollination, but in the selfed fruitlets the fertilised ovules got aborted due to abnormalities in the proembryo and endosperm and due to overgrowth of the cells of the nucellus (Sharma and Singh,1970a). Physiological studies, conducted later at IARI, showed that the level of auxin like substances was higher in the cross-pollinated fruitlets, as compared to that of the self-pollinated ones (Pandey *et al*. 1972). A study utilising ^{32}P further indicated that the cross-pollinated fruitlets act as a stronger physiological sink in which nutrients and other metabolites move preferentially, as compared to the selfed fruitlets. The levels of RNA and DNA were also found to be higher in the cross-pollinated fruitlets (Pandey *et al*, 1974).

5.9 Fruit-growth and Development

This aspect has been studied in the case of the varieties Dashehari, Langra and Chausa (Singh. 1954a) and the growth curve is of the sigmoid type (Singh, 1978).

Development of the fruits in the varieties Langra and Dashehari starts in the last week of March and is completed by the second week of June. Percentage increase in growth (in terms of length, breadth and thickness) is highest in April, followed by that in May ; least growth being in the month of June. However, maximum increase in weight and volume occurred in May, followed by April and June (Saini *et al*, 1971). Growth of fruits and biochemical changes during development in varieties Himsagar and Fazli are reported by (Chattopadhay *et al*, 1980 and Bose *et al*, in press).

The period of rapid growth in mango is directly related to the content of auxin and gibberellin like substances in the seed (Chacko *et al*. 1970). Failure in fertilisation of the ovule or its subsequent post-fertilisation abortion (as occurs

in incompatible pollination) lead to complete cessation of fruit growth and result in fruit drop.

Natural parthenocapy is not reported to occur in mango. However, exogenous applications of N^6-Benzyladenine (250 ppm) at anthesis, and later a combination of β-naphthoxyacetic acid (10 ppm) and GA_3 (250 ppm) at fortnightly intervals, resulted in the production of seedless fruits in Dashehari. These fruits, although smaller in size, were superior in fruit quality as compared to normal seeded fruits (Chacko and Singh, 1969). These studies have little practical value and are of academic interest.

Fruit drop

The natural fruit drop in mango is rather too high ; amounting to about 99 per cent at various stages of growth more especially during the initial four weeks (Singh, 1960 ; Singh, 1960). In the varieties Bombai, Langra and Fazli about 13 to 28 per cent of the perfect flowers set fruit and only 0·1 to 0·25 per cent reach maturity stage (Sen, 1939). Studies conducted by various workers show that in mango, in general, only about 0·1 per cent of the perfect flowers develop fruit to maturity (Bijhouwer, 1937 ; Naik and Rao, 1943 ; Singh, 1954a). The extent of fruit drop appears to be a varietal characteristic.

Amongst the causes attributed to this phenomenon are lack of pollination, low stigmatic receptivity, defective perfect flowers (having defective embyro sac development at anthesis), poor pollen, transference, occurrence and extent of self-incompatibility ; competition between developing fruitlets and drought or lack of irrigation (Singh, 1960 ; Sharma and Singh, 1970, 1970a). Some other contributing factors are unfavourable climatic conditions during fruit development period (viz., winds and hailstorms), high incidence of serious diseases like powdery mildew and anthracnose and pests like hopper and mealy bug (Hayes, 1957 ; Singh, 1960).

The extent of fruit drop in mango can be reduced significantly by regular irrigations during the fruit development period. Timely and effective control measures against major pests and diseases can also be of great help.

Attempts have also been made to control fruit drop through the application of plant regulators like NAA and 2,4-D. Gokhale and Kanitkar (1951) reported that post-setting drop in var.Alphonso could be checked by the application of these regulators at 25 ppm concentration. Subsequently, 2,4-D (30 ppm) has given good results in controlling fruit drop in var.Neelum, without having any adverse effect on fruit size or TSS (Rao and Subbarao, (1963). Roy *et al.* (1963) also observed some reduction, but at lower concentrations (5 and 10 ppm), in the varieties Gulabkhas, Himsagar, Langra and Bombai. Gill (1966) tried a number of growth regulators including 2,4-D, NAA and 2,4,5-T in the varieties Dashehari, Langra, Chausa and Bombay Green. Of these 2,4-D

appeared to be the best at concentrations lower than 20 ppm about six weeks after fruit set (end of April). Though these treatments resulted in harvesting of 3 to 50 per cent more fruits than the control, its deleterious effects on fruit development were, nevertheless, quite common. In the variety Dashehari, foliar application of urea (2 per cent) proved effective in increasing the harvest as compared to control.

However, a review of the work done so far on controlling fruit drop through plant growth regulators reveals that their applications have not given any material gain in fruit retention during the 'on' year, when the crop load is heavy and the drop is also more. During the 'off' year more favourable results have been obtained (Chadha, 1963) but these do not seem to be of any practical significance.

5.10 Biennial Bearing

This is one of the most burning problems since it renders mango cultivation less remunerative to the growers. This term is synonymous to 'alternate' bearing which denotes yield variation in alternate years, i.e., an year of optimum or heavy fruiting is followed by an year of little or no fruiting. This is an age old phenomenon, common to almost all the varieties of mango, and finds mention even in *Ain-e-Akbari* written by Abul Fazal during the reign of Emperor Akbar. The few varieties of mango which are exception to this rule are grown in southern India and are, on the other hand, relatively inferior in fruit quality.

The terms periodicity of cropping and irregular bearing are sometimes erroneously used to describe the phenomenon of biennial bearing. These terms do not imply variation in yield in alternate years. The terms irregular bearing and periodicity of cropping imply that cropping does not follow a systematic pattern, i.e., an optimum crop is obtained only once in a number of years. Such a behaviour is largely due to lack of proper orchard management practices. On the other hand, the alternate or biennial bearing habit is of a genetic nature since this trait can be identified amongst the mango plants right from the initial years of fruiting. This is contrary to the viewpoint prevalent in the literature (Singh and Khan, 1940 : Gandhi, 1955 ; Singh, 1960), wherein it is mentioned that the biennial bearing habit sets in only after the age of 10-12 years. The observations made during the last two decades at the IARI, on the bearing behaviour of hundreds of hybrid seedlings, have established that regular and biennial bearing hybrids can be identified right in the second year of fruiting.

The problem of biennial bearing has been studied in great depth by a number of workers during the last 4 decades or so (Singh, 1960 Singh, 1978). Several aspects like climatological factors, age and size of shoots, C/N ratio and hormonal balance have been investigated into with a view to arriving at a better understanding of the problem and for providing a solution to this problem.

Climatological factors

Adverse climatic conditions like rain, high humidity and low temperature sometimes convert an 'on' year into an 'off' year directly or by promoting the incidence of diseases like powdery mildew and anthracnose. Frequent frosts or low temperatures during the flowering period adversely affect the fruit set, thereby turning an 'on' year into an year of low crop or no crop. Climatological factors, as such, do not form the basic cause of biennial bearing.

Age and size of shoots

As early as 1935, in the Philippines, Galang and Lazo reported that the variety Carbao would not differentiate flower buds unless the shoots are of certain length and girth and with a number of leaves of particular size. It has also been reported by some earlier workers in India (Singh and Khan, 1940 ; Naik and Rao, 1942 ; Roy, 1953 ; Singh, 1960) that of the various vegetative flushes, varying from 3 to 5 in different parts of the country, it is the earliest emerged flushes, which experience certain dormant period (without any further extension growth) and are of 8 to 10 months maturity, which are capable of producing flower buds. This necessarily means that a certain amount of physiological maturity is pre-requisite to flowering in the case of varieties which are prone to this phenomenon.

However, studies conducted at Saharanpur (Singh, 1959) have shown that in the case of the regular bearing variety Romani, even December-emerged shoots are capable of producing flower buds in the following February. This has also been established in another regular bearing variety Neelum, wherein shoots emerging in October were in a position to flower by the following March (Singh *et al*, 1962). However, this is not the case with biennial bearing varieties.

In the biennial bearing variety Dashehari, even when shoots of desired maturity were induced to the extent of 83·0 per cent (following defruiting at 'pea' stage in the last week of March), only 15·2 per cent of these flowered next year (Singh *et al*, 1968). This clearly suggests that a vast majority of the non-flowering shoots (though of correct maturity) were probably lacking in some vital substance or substances necessary for flower bud formation. The tree, therefore, takes an year to recoup this loss, thus causing biennial bearing habit in the tree.

In the light of the present knowledge, none of these earlier theories, about age and maturity of shoots, appear to hold good. In an 'on' year, shoots of any size or maturity differentiate flower buds whereas in an 'off' year, even if the shoots of requisite size and maturity are available, they fail to flower.

Carbon/nitrogen ratio

The C/N ratio, in relation to flowering in mango (var. Langra) was first studied by Naik and Shaw (1937) but no definite conclusions could be arrived

at. Subsequently, Sen (1943) reported that irregular bearing in mango is caused by nutritional deficiency, especially that of nitrogen. He further reported that a proportionate increase in nitrogen leads to vegetative growth whereas its proportionate decrease favours flowering (Sen, 1946).

Studies on this aspect have since been conducted by a number of workers (Mallik, 1953 ; Singh, 1960 ; Sen *et al*, 1963) and it is indicated that higher starch reserves, total carbohydrates and C/N ratio favour flower bud formation in most of the varieties studied except Baramasi and regular bearing varieties.

Studies on the nitrogenous constituents in the stems and leaves of different varieties of mango indicated higher amounts in the trees which were expected to flower, although no correlation between flower bud initiation and total nitrogen content could be derived (Singh, 1960 ; Singh, 1960 ; Sen *et al*, 1963 ; Chacko, 1968).

The available evidence suggests that in fruit plants, nitrogen and carbohydrate reserves play an important role in flower bud initiation, even if these do not form the primary cause of the phenomenon of biennial bearing (Singh, 1978). It is quite probable that an accumulation of these compounds may be creating favourable conditions for the synthesis and action of the substances responsible for flowering.

Hormonal balance

The problem of biennial bearing in mango appears to be closely associated with the fruit development process and the inhibitory influence of the developing fruits on vegetative growth (Singh, 1960 ; Singh *et al*, 1968).

Studies conducted on the physiological aspects of the flowering process in mango have shown that higher levels of auxin like substances and an inhibitor (similar to ABA) and lower levels of gibberellin (GA_3) like substances are vital for a floriferous shoot in mango (Chacko, 1968). Further studies are needed to bring about an ideal combination of these substances in precise amounts and in correct sequence. However, it seems rather impossible in a crop like mango which is rather unmanagable in comparison to annuals.

The distinct difference in the bearing behaviour of the regular and biennial bearing varieties leaves hardly any doubt that the problem is an inherent one and a lasting solution can only be obtained through genetic engineering.

Control of biennial bearing problem

The biennial bearing problem has been a major bottleneck in the expansion of the mango industry. The growers have to split the profits of an 'on' year into two, in order to take care of the 'off' year. Also, because of glut in the 'on' year, the price offered to the orchardist is less remunerative. During an 'off' year or

an year of low production, the consumer too has to pay an exorbitant price for the fruit. Obviously, this problem has, therefore, posed a major challenge to the horticultural scientists during the last seven decades. Consequently, a number of remedial measures have been proposed from time to time to overcome this limitation in mango production. These included proper upkeep and maintenance of the orchards, deblossoming, smudging and crop regulation through chemicals, pruning, and growing of regular bearing varieties.

Proper upkeep and maintenance of orchards : A proper cultural schedule is of paramount importance for maintaining fruit trees in healthy and disease-free conditions, and thereby, obtaining better plant performance. Wagle (1931) reported that proper manuring of mango orchards (10 to 12 year-old) leads to the solution of this problem. A number of other cultural practices like root pruning, application of salt and giving incision to the bark were advocated by Balakrishnamurti and Jogiraju (1932). Necessity for regular ploughing thrice a year (in autumn, winter and beginning of monsoon), liberal manuring with farm-yard manure or compost, irrigation after fruit set, ringing of branches in high rainfall areas and regions of late rains, and keeping the orchards open has also been emphasised by Sen (1943) for overcoming this problem.

However, these treatments have not been found to be of any help (Cheema *et al*, 1954 ; Gandhi, 1955 ; Singh, 1961 ; Singh, 1978). Experience shows that proper maintenance of trees may help in reducing erratic or irregular bearing but it cannot induce regularity of bearing in biennial varieties.

Deblossoming : This practice has been recommended by some earlier workers with a view to obtaining some crop every year, by reducing the crop load in the 'on' year (Singh and Khan, 1939, 1940 ; Sen, 1943). According to these workers the shoots deblossomed in the 'on' year put forth panicles in the following year which would otherwise be an 'off' year.

Singh (1961) reported that response to deblossoming depends on the variety ; the variety Dashehari responding somewhat better than Langra. This will have to be done once in 10 years on big units (a branch) on a tree, rather than on individual shoots. However, later studies conducted at the IARI have shown that this deblossoming can be helpful only at the full development stage of the panicles and not earlier (Singh *et al*, 1974).

Smudging and chemical regulation : Induction of flowering in mango through 'smudging' (building up slow fires, emitting smoke) is an age-old practice in the Philippines (Gonzalez, 1923 ; Wester, 1924 ; Galang and Agati, 1936). Some attribute the flowering to heat whereas the others hold CO_2 responsible for this. However, these have not been found to be helpful in India (Cheema *et al*, 1954). In recent years, Ethrel (2-chloroethane-phosphonic acid) has also been tried to induce flowering in mango during the 'off' year and some success has also been claimed in this regard (Chacko *et al*, 1972 ; Pandey *et al*, 1973). However, large

scale trials conducted at the CMRS (Lucknow) and in some private orchards at Faridabad and Khurja in Uttar Pradesh did not yield favourable results and efficacy of this chemical is doubtful. At the most it can merely hasten flowering by a few days in an 'on' year. More recently, Auxin-61 and KNO_3 have also entered this area and their role, if any, is still under investigation.

Pruning: Relatively recently it has been reported that pruning can be helpful in overcoming the problem of irregular bearing in mango (Madhava Rao, 1971). This type of pruning is recommended for opening the centre of the tree by topping off or thinning of branches. This is reported to have helped in reducing irregular bearing.

However, these recommendations cannot be helpful in biennial varieties which do not have the genetic potential to bear regularly. This practice can be of help in permitting light in old and neglected orchards and in improving their erratic fruiting.

Growing regular bearing varieties: Choice in this regard is rather limited since only a few of the hundreds of mango varieties are regular in bearing and these are grown commercially only in the South. Although these are relatively inferior in fruit quality, and late in maturity under North Indian conditions, these can be tried to obtain regular cropping in areas where the local varieties are all biennial.

Besides the traditional regular bearing varieties (viz., Bangalora, Neelum, Totapari Red Small, Romani), two improved varieties developed at the IARI (viz., Mallika and Amrapali) should also be tried in different regions (Table 3).

The variety Mallika is semi-vigorous in habit and has a strong tendency to bear every year, besides having fruits of larger size (about 300 gm/fruit) and superb fruit quality (Singh *et al*, 1977). The variety Amrapali is precocious, distinctly dwarf, highly regular and prolific in bearing and has good fruit quality (Sharma *et al*, 1981). This is a variety with a future since it has been found to fit into the concept of high density orcharding which will lead to higher plant density per unit area, better management and manifold increase in yield.

TABLE 3. FRUIT QUALITY OF 'MALLIKA' AND 'AMRAPALI' ALONG WITH THEIR PARENTS

Particulars	IARI varieties		Parents	
	Mallika (Neelum x Dashehari)	Amrapali (Dashehari x Neelum)	Neelum	Dashehari
Average fruit weight (gm)	307·0	143·0	120·0	155·0
Pulp (%)	74·9	74·8	59.1	68·0
Total soluble solids (°Brix)	24·0	22·8	18·0	21·0
Total sugars (%)	18·6	17·2	16·4	15·2
Acidity (%, Citric)	0·33	0·12	0·28	0·19
Ascorbic acid (mg/100 gm)	19·0	35·0	31·0	37·0
Total Carotenoid pigments (expressed as β-carotene ; μg/100 gm)	10,392	16,830	5,275	7,452

5.11 Pests and Diseases and Physiological Disorders

Pests

Though the list of pests attacking mango is formidable, only two of these are considered to be devastating, viz., mango hopper (*Idiocerus* spp.) and mealy bug (*Drosicha mangiferae* Green). Amongst others are stem-borer *Batocera rufomaculata* De Geer and *B. rubus* Linn.), shoot-borer (*Chlumetia traversa* Wlk.), bark-eating caterpillar (*Inderbella* sp.), leaf-cutting weevil (*Deporus* (*Eugnamptus*) *marginatus* Pasc.), shoot-gall maker *Apsylla cistellata* Buckton), leaf-gall maker *Procontariana matteiana* Kieff and Cecec, *Amraemyia* sp.), fruit fly (*Dacus* spp.), stone-weevil (*Cryptorrhynchus* (*Sternochetus*) *mangiferae* F. and C. *gravis* F.), blossom midges (*Desineura amramanjara* Grover), and red ants (*Oecophylla smargidina* Fab.)

Mango hopper : This is the most damaging insect during the flowering season. Until February, the hoppers remain in hiding under the bark crevices and become active during flowering period. Both adults and the nymphs are damaging, especially the latter which have a higher rate of feeding. They suck the sap from tender shoots and panicles. The panicles wither away and the fruit-set is adversely affected. Injury caused by oviposition further aggravates the situation. They give out 'honey dew' which develops a 'sooty' mould on the leaves and panicles.

Its incidence is very high in overcrowded and neglected orchards. It can be controlled by spraying with Malathion (0·15%)/Diazinon (0·02%)/Endrin (0.04%)/Carbaryl (0·15%)/Phosphomidon (0·05%) or Nuvacron (0·04%) once at the time of panicle emergence and then again at the fruit-set stage.

Mealy bug : The female lays eggs during May under soil clods, around the tree trunk, up to a depth of 5 to 15 cm. The nymphs emerge in December-January and start climbing up the tree where they congregate together and suck juice from young shoots, panicles and flower pedicels. The affected parts dry up and yield is reduced substantially.

The females can be identified by their flat shape covered with white mealy powder. Once the pest manages to reach the top of the plant, its control becomes rather difficult. Damage from the mealy bugs can be avoided if the eggs are destroyed by digging around the trunk during hot months. Sticky bands (greese and coal tar in the ratio of 1 : . ; rosin and castor oil in the ratio of 4 : 5) or slippery bands of alkathene, 30 to 45 cm wide should be applied around the tree trunk about 30 to 45 cm above the ground level during December. However, before applying these bands, care should be taken to plaster all the bark crevices with mud so that the nymphs may not climb up from underneath such bands. Alkathene bands need to be wiped clean at least once a week and the nymphs on the lower edges may be collected and destroyed in kerosene oil or any strong

insecticide. In case the nymphs have climbed up the tree, these should be controlled at the earliest by spraying Carbaryl (0·2%) or Nuvacron (0·04%).

Stem borer : This pest tunnels through the main trunk or its branches, weakens the plant, and in extreme cases, the plant may die. Its presence can be indentified by dry hard balls (small-sized) of excreta emerging from the tunneled portion. The control lies in cleaning the tunnels with a hard wire, pouring the kerosene oil/creosote/petrol/crude oil or formalin, and subsequently, closing the entrance of the tunnel with mud after plugging it with cotton wool soaked in any of the above substances.

Shoot borer : The damage is caused by caterpillars which enter the young shoots from the terminal end and bore down to a depth of 8 to 10 cm. The affected shoots wilt and dry. It can be controlled by 1 or 2 sprays of Carbaryl (0·2%) or Nuvacron (0·04%) during the emergence period of vegetative flush.

Bark-eating caterpillar : The caterpillar bores into the bark, and at times, makes a tunnel through the stem or the branch. Its incidence can be identified by dark brownish excreta appearing in the form of a ribbon covering the affected patch of the bark. The affected limbs are weakened by disruption of the sap flow in the tree, often the affected branches dry up. It can be controlled by cleaning the affected portion and killing the caterpillar mechanically by inserting a metallic wire in the tunnel and then injecting kerosene oil/petrol/ethylene glycol and kerosene oil mixture in the ratio of 1 : 3. The entrance of the tunnel should be plugged with cotton and plastered immediately.

Leaf-cutting weevil : This cuts the newly emerged leaves at the base of the lamina in the form of a clear and sharp cut. The shoots, thus defoliated, lose vigour and get weakened. Its damage in the nursery can be avoided by applying BHC dust to the newly emerged shoots. On grown-up plants the damage can be checked by Malathion spray (0·1%), which should be repeated, if necessary, during the period of vegetative flush.

Shoot-gall maker : The damage through this insect is widely prevalent in the northern region, especially in the 'Terai' area of Uttar Pradesh. This minute insect lays its eggs in rows of two, on the underside of the leaves of new flush (March-April), along the mid-rib. The eggs hatch in about 5 to 6 months. The nymphs, on emergence, enter the axillary and terminal buds and turn them into hard conical galls through their secretion. This generally affects the growth of the shoot and the inflorescence. However, there is hardly any effective and efficient control against this pest. Parathion (0·04%) or Endrin (0·04%) sprays during February, i.e., just before the egg-laying period, have resulted in the reduction of the pest. Satisfactory control can also be obtained by spraying Metasystox (0·1%), twice during September, i.e., during hatching of nymphs.

Leaf-gall maker : Its incidence is characterised by the presence, on the leaves, of round and raised galls of various colours (viz., grey, green and brown) depending upon the species. The eggs are laid on the underside of the leaves during March, July and October. The maggots, on hatching, bore into the leaf tissues giving rise to galls on the upper surface of the leaves. The leaves are rendered useless by continuous draining of the sap by the larvae feeding inside the gall. No definite control measures have been evolved as yet. However, 4 sprays of Tar oil (2 to 3%) during the egg-laying period, at weekly intervals, can be of some help in reducing the incidence. Endrin (0·04%) sprays are also thought to be effective against this pest.

Fruit-fly : This is a serious pest as the affected fruits become unfit for consumption through the feeding of the maggots in the flesh. The fruit fly lays its eggs in clusters of 150-200 under the skin of the fruit just before ripening. The affected fruits begin to rot and drop down.

The control lies in prompt collection and destruction of the damaged fruits in hot water or by burying them deep in the soil. Poisoned baits placed in wide-mouthed containers @ 10 per hectare are helpful in checking the incidence of fruit fly. The formulations reported to be effective are (i) sodium fluosilicate (1 part) and molasses or syrup (6 parts) in water (100 parts) : (ii) lead arsenate (1 part) and molasses (24 parts) in water (100 parts) and (iii) 100 ml emulsion of methyl euginol (0·1%) and Malathion (0·1%). The flies can also be controlled by bait sprays of Carbaryl (0·2%)+ protein hydrolysate or molasses (0·1%), beginning at egg laying stage.

Stone or nut weevil : This is mostly prevalent in the southern parts of the country and is reported to be specific to sweet varieties of mango. Grabs of *C. mangiferae* (more commonly occurring) damage both the pulp and the cotyledons of the stone whereas those of *C. gravis* develop in the pulp and eat only the fibre of the stone. The eggs are laid in partly developed fruits. The grabs travel through the pulp and enter the seed where these pupate and the adults come out piercing through the stone and the pulp. General cleanliness in the orchard and destroying the adults, in the bark crevices and holes, during August have been reported to be helpful. Infested bark should be washed with kerosene emulsion.

Red ants : These are widely prevalent in mango growing areas all over the world and cause damage to the mango tree indirectly, i.e., they render the new leaves useless for photosynthesis since these are moulded together in the form of a nest by the silken substance excreted by larvae. Also, these nests serve as distribution centres for various kinds of scales and mealy bugs, both living and dead, on which they feed.

The red ants can be effectively controlled by destroying the nests or by putting in lead arsenate in the nests (@ 1/2 teaspoonful/nest). The affected trees can be sprayed with Endrin (0·02%) or Dieldrin (0·03%) to keep these ants in check.

Diseases

Amongst the diseases most damaging to mango are the powdery mildew (*Oidium mangiferae* Barthet) and anthracnose (*Colletotrichum gloesporiodes* Penzig.); the damage caused by other diseases like stem-end rot (*Diplodia* spp.), sooty mould (*Meliola mangiferae* Earle) and pink disease (*Pellicularia salmonicolor* Berk & Br.), (*Botryobasidium salmonicolor* Berk & Br.), (*Corticum salmonicolor* Berk & Br.) is serious only in certain areas. Bacterial spot (*Pseudomonas mangiferae indicae* sp.) is also common in humid areas, especially in the North.

Powdery mildew: This fungal disease is widely prevalent in all mango growing regions and can even completely destroy the crop. Its incidence is favoured by high humidity accompanied by cloudy weather and low night temperatures during the period between panicle development and fruit set. It is characterised by the appearance of greyish-white powdery bloom on the flower buds and fruitlets. Quite often the entire panicle may be affected. Such panicles get dried and turn black; resulting in total failure of the crop. In serious cases, even young leaves and shoots may be affected.

It can be controlled by timely applications of wettable sulphur (0·2%) /Kerathane (0·1%)/Bavistan (0·1%) or Benlate (0·1%). The first spray should be given at pre-bloom stage, as a preventive step, in areas more prone to the incidence of this disease. If necessary, this may have to be followed by two more applications at full bloom and fruit-set stages (at fortnightly intervals). In years of persistent and servere infection the interval between sprays may have to be reduced to a week and even additional sprays may be required if there is rain immediately after spraying.

Anthracnose: This fungal disease is also of wide occurrence, more especially in humid and high rainfall area. The leaves, shoots, inflorescence and the fruits are all affected by it. The characteristic symptom is the appearance of black necrotic areas on the affected parts. The affected young shoots finally show die-back symptoms. The diseased young fruitlets drop down and if the fungus attacks the fruits at maturity, the disease is enhanced by storage.

As the fungus survives on dead or dried twigs, these should be pruned and burnt at the earliest. The disease can also be controlled by spraying Bordeaux mixture (3 : 3 : 50)/Blitox or Phytolan (0·3%)/Bavistan (0·1%) or Benlate (0·1%) thrice a year, i.e., February, April and September. In case the symptoms persist, even up to 8 sprayings may be necessary for controlling this disease. Affected full grown fruits should be dipped in hot water (51 °C) for 15 minutes, before storage.

Sooty mould: The disease is common in areas where 'hopper' build-up is intense. The fungus develops on the honey dew secreted by the hoppers on the leaves, twigs and inflorescence. The damage caused is due to restricted photosynthetic activity of the affected leaves.

Pink disease : This is a serious disease in southern parts of the country, more especially in Kerala where inoculum is present on the plant and humid conditions favour its further spread. Initially, the fungus affects the bark of the young branches (below or above the forks or crotches). Portions of the bark die and peel off from the wood ; resulting in some sort of ringing of the branch. The terminal portions of the branch, above the damaged area, die out along with the foliage. The disease continues to develop beyond the areas affected initially and pink coloured encrustations with irregular fine cracks, are formed. The infection may spread to woody tissues also, ultimately killing them too.

An effective control can be obtained by pruning the affected branches at least 30 cm below the infected area at the initial stage. The cut ends of the branches may, then, be protected with a weak fungicidal paint like Bordeaux paste (1 : 1 : 30).

Bacterial canker or bacterial spot : The earliest symptom of this disease on the leaves and the fruits, is the appearance of small dark green water-soaked spots which finally assume the shape of a raised black spot. These areas on the fruits develop longitudinal cracks and gum starts oozing out from the splits. Seriously affected fruits drop down and the yield may be adversely affected. Affected fruits are unattractive and unmarketable.

This disease is widely prevalent and the infection increases with recurrent rainy weather. However, all the varieties are not affected equally. The varieties Bangalora and Neelum are more commonly affected, especially in the North. Rarely, this is encountered in Dashehari also. The variety Mallika has the drawback, especially when the fruit maturity period happens to be humid and rainy. In dry seasons the incidence is not noticed

Although no satisfactory control measures are available as yet. Bordeaux mixture (4 : 4 : 50) may be applied at fortnightly interval from the first appearance of the disease on the leaves. The sprays are to be repeated immediately after a rain. Recently, two sprays of Streptocycline (200 ppm) have been found to be helpful in reducing the incidence of this disease (Bose and Singh, 1980).

Parasites

Uncared mango orchards are commonly infested with members of the Loranthaceae family, which damage from 60 to 90 per cent of the mango trees in the North (Singh, 1960). The most destructive parasite in this category is *Dendrophthoe falcata* (L. f.) (earlier known as *Loranthus longiflorus* Desr.) followed by *Macrosolen cochinchinensis* Van Tiegh, *Helicanthes elasticus* Dans. and *Elytranthe capitellata* Engl.

These parasites result in retardation of the growth and yield of the trees and degradation in fruit quality. In more serious cases, the plant may even die. The only dependable method of controlling this parasite is through cutting off the

infected branches much below the affected area to eliminate all vestiges of the haustorial system from the host plant. Other methods, utilising chemicals and oil emulsions, have also been tried to control Loranthus but the results are not consistent.

Physiological Disorders

Black tip : This is widely prevalent in Punjab, Uttar Pradesh, Bihar and West Bengal. The distal ends of the fruits turn black and get hardened. The affected fruits become ripe prematurely and unmarketable.

This condition is caused by the fumes emanating from the brick-kilns located near the mango orchards. The distance to which these can cause damage is reported to be about 700 yards (630 metres), although damage has also been noticed up to a distance of 1 mile (1.6 km). This disorder is quite common if the fruiting orchards fall in the direction of the wind from the brick-kiln side.

Gases like carbon dioxide, sulphur dioxide and acetylene which constitute the brick-kiln fume are reported to cause the symptoms and its incidence on fruits is inversely proportional to the distance of the orchard from the brick-kiln (Ranjan, and Jha, 1940 ; Sen, 1943a). Varietal differences, in regard to susceptibility, have also been reported ; the varieties having large number of lenticels per fruit being more susceptible (Sen, 1943a).

The disorder can be avoided by allowing brick-kilns only at a distance of at least 1·6 km in the east and west, and 0·8 km in the north and south of the orchard ; taking into consideration the usual wind direction during the fruiting season. The chimney height should also be increased to at least 15 to 18 metres to minimise the damaging effects of the smoke in the orchard. Amongst the chemicals tried to prevent the occurrence of this disorder are borax (0·6%) and caustic soda (0·8%) which have given good control (Das Gupta and Sen, 1958 ; Naurial *et al*. 1972). These should, preferably be sprayed thrice, i.e., before flowering, during flowering and at the fruit-set stage.

Leaf scorch : The characteristic symptom is akin to that of potash deficiency, i.e., scorching of old leaves at the tips and margins. This condition is quite common during the winter months when the entire old foliage in some regions appears to be affected by these symptoms. The leaves fall down and the tree-vigour and yield are reduced.

Studies conducted on this disorder have shown that it is caused by an excess of chloride ions which render potash unavailable (Pandey *et al*, 1971). This disorder is common in saline soils or where brackish water is available for irrigation or where muriate of potash is used as a fertiliser to meet the potash requirements of the plants.

This disorder can be checked effectively by collecting and burning the fallen leaves, and using potassium sulphate instead of muriate of potash. Acute

condition can be cured by 4-5 foliar applications of potassium sulphate (5%) on newly emerged flushes at fortnightly intervals.

Spongy tissue : This disorder is common in the fruits of the variety Alphonso, where it is observed to an extent of as high as 30 per cent. Apparently normal and attractive fruits, on cutting, reveal spongy development in the flesh. The fruits have a bad odour and become unpalatable. This disorder has adversely affected the export market of this delicious variety.

The causes leading to this phenomenon are still being investigated into and to-date no difinite conclusions have been possible. However, it is reported that harvesting the fruits at full maturity increases the incidence of the disorder, whereas on harvesting at 3/4 maturity stage, the incidence is negligible. Involvement of calcium is also indicated with its incidence (Gunjate *et al*, 1979).

5.12 Mango Malformation

The disorder was first noticed by Maries (c. f. Watt, 1891), in the Indian subcontinent, towards the end of the last century. Now it is known to occur in the Middle East, Africa, Israel, Central America, Mexico and the USA, (Varma *et al*, 1974).

During the last two decades or so it has assumed an alarming magnitude in the northern India where it is threatening the very existence of the mango industry. It is of wide occurrence in Punjab, Delhi and western Uttar Pradesh and its incidence is also noticed to some extent in Gujarat and Maharashtra. It is negligible in Bihar, West Bengal and Orissa. The southern mango growing regions, beyond Hyderabad, are virtually free from this malady.

Mango malformation is of two types---vegetative and floral ; the former being more common on the nursery seedlings and young plants and, the latter, on trees at the bearing stage. It is the floral malformation which directly affects the productivity.

The incidence of this disorder varies from year to year and variety to variety ; the highest being in the varieties Chausa and Bombay Green, i.e., up to 90 per cent. The only variety known to be free from floral malformation is Bhadauran which, on the other hand, is very inferior in fruit size and quality (Prasad *et al*, 1965).

This malady has attracted the attention of many workers and various causes have been attributed to this from time to time, viz., cultural practices (Watt, 1891), nutritional (Tripathi, 1955 ; Prasad *et al*, 1965), mites (Narasimhan, 1954, 1959 ; Narayanan and Ghai, 1961), virus (Sattar, 1946 ; Puttarudriah and Channa Basavanna, 1961), fungus (Summanwar *et al*. 1966). However, the picture is still

confusing and general consensus on the precise causal organism/substance is yet to be reached.

Studies conducted at the Division of Horticulture of the IARI, since 1966, have revealed that the floral malformation is broadly of three types, i.e., light, medium and heavy. The heavy type is the most damaging because of its failure to set any fruit. Such panicles are characterised by a condensed mass of flower buds which are largely male (Majumder and Sinha, 1972). These panicles show suppression of apical dominance and have a tendency to hang on the tree around the year and, in this process, these rob the tree of essential nutrients. In the light and medium types, flowers of both sexes are found on the panicles and some fruit-set can also be seen, though it is rare. In such cases, it is not uncommon to find a part of the panicle normal, whereas the other portions are malformed. Also occasionally, healthy and malformed flowers are encountered side by side even on the same panicle which is, otherwise, apparently quite normal looking.

A better understanding of this phenomenon was reached at the IARI during the 1968 flowering season (February-March) when the variety Neelum showed an incidence of as high as 59 per cent. Since these panicles got damaged due to severe frost, the tree flowered again in June, when the incidence of floral malformation was found to be as low as 4·5 per cent. The maximum temperature during the development of March flush of panicles was found to range from 21 to 30°C whereas at the time of June flush it was as high as 39°C. This observation was later confirmed by creating warmer conditions during March, similar to June (42 to 45°C), in a polythene tent enclosing a plant of the variety Neelum. The enclosed tree had 60 per cent floral malformation in the previous year but its incidence under the tent was totally absent (Majumder and Sinha, 1972a). These studies led to the conclusion that an inverse correlation exists between temperature and the incidence of malformation.

Observations at this Institute, in general, have shown that the incidence of floral malformation in the early flush of panicles is much higher than in the late emerged panicles. Later studies have shown that deblossoming of the early flush of panicles at the 'bud-burst' stage (when the panicles are about 1½ to 2 cm long) can shift the flowering to a later date, when the temperatures are higher. Panicles emerging after deblossoming, during the same fruiting season, showed a significantly lower incidence of malformation and a higher fruit-set (Singh *et al*, 1974). The increased fruit-set was possibly due to an improvement in the sex ratio due to high temperatures (Singh *et al*, 1966) and significant reduction in the number of heavily malformed panicles of the hanging type as well as the others.

An analysis of the healthy and malformed panicles in 4 varieties has shown that the former have higher levels of RNA, DNA, soluble proteins and total nitrogen than the latter (Pandey *et al*, 1975). However, the concentration of all the fractions of carbohydrates (viz., reducing, non-reducing, polysaccharides and

total carbohydrates) was higher in the shoots showing vegetative malformation. On the contrary, the nitrogen fractions were always less in such shoots (Pandey *et al*, 1973a). Detailed chromatography and bioassay studies indicated higher levels of all the four fractions of auxin (viz., free neutral, free acidic, bound neutral and bound acidic) in healthy flower buds, as compared to malformed ones (Pandey *et al*, 1974a). The levels of inhibitors showed a reverse trend.

Improving the productivity of trees affected by malformation

Studies conducted at the IARI have established that the productivity of the trees, rendered unproductive by malformation, can be improved by a single spray of NAA (200 ppm) in the first week of October, and deblossoming once at the bud-burst stage (Majumder *et al*, 1970 ; Majumder *et al*, 1976).

These recommendations have been tested over the years in large-scale field trials conducted in different locations in Delhi, Haryana, Uttar Pradesh and Punjab.

5.13 Harvesting

Stage of maturity

The stage at which the fruits should be harvested has an important bearing on ripening and fruit quality. Unless the fruits are harvested at the correct stage, when they have attained full size, the characteristic taste and flavour of the variety cannot develop.

The various criteria recommended for judging maturity are—(i) slight colour development on the shoulders (Cheema and Dani, 1934 ; Wardlaw and Leonard, 1936), (ii) when one or two ripe fruits fall from the plant naturally, and (iii) when the specific gravity of fruits ranges between 1·01 and 1·02 (Singh, 1960). The first two methods are not of much help since these are not representative of the fruit maturity of the entire tree and the fruits harvested do not ripen uniformly. The last method (Harkness and Cobin, 1951 ; Mukerjee, 1960), based on specific gravity, is more dependable. For this, fruit samples from various directions of the tree are taken and dropped in a bucket of water ; the dipped fruits being indicative of the correct maturity.

Number of days taken by the fruit to mature depends on the variety and the climatic conditions and, hence, cannot serve as a guide. However, in general, fruits mature between 90 to 120 days from the fruit-set stage.

As yet, no single criterion for judging maturity correctly has been worked out (Rao *et al*, 1970, 1972 ; Hulme, 1971, Krishnamurthy and Subramanyam, 1973). This aspect is of vital concern and needs further investigations.

Method of harvesting

The method of harvesting in mango is, in general, still primitive since the fruits are harvested by shaking the branches which results in internal breakdown of the flesh on falling and spoils the appearance also. In the other common method, the fruit picker climbs up the tree with a collecting bag on his shoulders and the fruits plucked are placed in the bag. This method, though more satisfactory, is rather impracticable because of the large size of the trees. Besides, there is danger of breaking the branches also.

The most satisfactory method available at the moment is the one which makes use of a bamboo hand tool, called mango picker. This consists of a long bamboo pole fitted with a cutting shear at the distal end, and under which a fruit collecting net is tied. However, harvesting of fruits from tall trees is problematic. Necessity is, therefore, felt for developing dwarf varieties through breeding.

5.14 Yield

It is a highly variable factor depending upon the variety and age of the plant, climatic conditions, incidence of pests and diseases and, above all, on the upkeep of the orchard.

The grafted plants of almost all the varieties start bearing at about the age of 4 or 5 years. The monoembryonic seedlings take a longer time to come to fruiting, ranging between 8 and 10 years whereas the polyembryonic types come to bearing earlier. The grafted plants of regular bearing varieties are precocious and start fruiting in the third year.

The seedling trees are very vigorous in growth habit, relatively long-lived and heavier in bearing. The fruit size and quality are highly variable and no two seedlings are alike in regard to these characters. Nevertheless, it is not uncommon to find them in good bearing even up to the age of 300 years (Popenoe, 1920). One seedling tree, named 'Chhappar' in District Ambala is reported to have a trunk circumference of 32'(9·75 m) and an area of 2700 square yards (2257·2 sq. m) (Randhawa, 1949). The yield is reported to be 450 maunds (16875 kg, approx). However, because of the serious disadvantages of seedling trees their cultivation is advocated no more.

The grafted plants, which are relatively short lived and less vigorous, bear fruits of highly uniform size and good quality. These start bearing at the age of 5 years (15-20 fruits) and the optimum crop starts from the 10th year when each tree yields about 400 to 600 fruits. The yield continues to increase up to the age of 40 years (2500 fruits), after which it starts declining (Singh, 1960). However, in certain grafted varieties like Langra and Chausa the full bearing potential is realised much later (15-20 years) than in a variety like Dashehari (10 years).

On the other hand, some grafted varieties are characteristically shy in bearing and their yield cannot be considered to be optimum or economical. These were probably selected for their fruit quality alone, viz., Himayuddin, Jehangir, Mulgoa, Allumpur Beneshan. The yield behaviour of the ever-bearing types like Baramasi, Dophala or Tephala is highly erratic and such varieties can hardly fit into the commercial concept of orcharding.

5.15 Packaging and Transport

The harvested fruits should first be graded according to size and appearance, although this is not the usual practice. Ripe fruits and damaged fruits of relatively poor quality are usually retained for local markets and better types are packed for distant places.

Proper packaging is an essential prerequisite for maintaining good appearance and quality of the produce on reaching the marketing centres. The most common practice in western India is to pack the fruits in bamboo baskets of 50 to 100 fruit capacity. This is followed in the district Malda (West Bengal) also. Sometimes straw is utilised as a cushioning material to avoid bruising injury to the fruit but this has not been found to be satisfactory (Contractor, 1951). Fruits of some hardy varieties like Bangalora are often loaded directly into the railway wagons without any sort of pakaging and these reach far off places in good condition (Cheema *et al*, 1954). However, one should bear in mind that fruits for distant markets are packaged when full grown but unripe. Quite often, a small packet of calcium carbide is also placed in the box while packing the fruits.

Besides bamboo baskets, wooden crates of various dimensions are also utilised in packaging mango (Singh, 1960). The dimensions of the crates or boxes vary with the variety to be packed. Cheema *et al*. (1954) recommended ventilated boxes, having 1/2" (1·3cm) diameter holes on the sides of the box. The wooden packing cases are, however, costlier and uneconomical. Also in recent times, wood is becoming scarce because of reckless denuding of forests. For this reason, emphasis is now being laid on utilising corrugated cardboard boxes which are lighter in weight and can be recycled. These are now being used exclusively for export purposes. However, for this purpose individual fruits are wrapped in tissue paper and cushioning is provided by paper shavings or wood wool. It is reported that Diphenyl-impregnated paper wrappers are good for reducing spoilage (Anandaswamy and Iyengar, 1961).

5.16 Storage and Ripening

Storage

The mango is a climacteric fruit and unless the fruits are stored properly, one cannot be sure of the condition in which the fruits will reach the desired market.

Proper storage is absolutely essential during the year of glut. Also, the processing units cannot utilise the entire produce at a time and proper storage conditions become vital.

In general, green but mature fruits store better than those harvested ripe from the tree. Studies have shown that fruits of many varieties can be stored successfully for about 4 to 7 weeks at a temperature of 3·9 to 8·9°C (Wardlaw and Leonard, 1936 ; Cheema *et al*, 1939 ; Karmarkar and Joshi, 1942). However, according to Srivastava (1967) storage temperature for various varieties ranges between 5·6 and 11·1 °C with a relative humidity of 85 to 90 per cent.

Another simple method advocated for enhancing storage life and for delaying ripening is that of wax coating (Bose and Basu, 1953). The fruits are treated with an aqueous wax emulsion made out of an indigenous raw material (Srivastava, 1967). Treatment with wax emulsion helps to reduce transportation and post-transportation losses in mangoes (Sharma and Kapur, 1967). This helps in improving the appearance and in prolonging the storage life. According to Garg *et al*, (1971) fruits stored at 29 to 35°C, and treated with 6 per cent Waxol-W-emulsion, and pre-packaging (1 kg lots in 200 gauge polythene bags with 0·6% ventilation), or waxed and stored at 5·5–7·2 °C, resulted in reduction of weight loss and spoilage, with prolonged shelf-life.

Attempts have also been made to increase storage life by irradiation (Dharkar *et al*, 1966 ; Ahmad *et al*, 1972), controlled atmosphere (Hatton and Reeder, 1966) and freezing (Srivastava, 1967) but, presently, these are more of an academic interest.

Ripening

Usually, the fruits ripen in about 5 days under tropical conditions and become over-ripe in 7 to 8 days. The usual practice in vogue is to place the fruits in layers, one above the other, with a straw padding (wheat or paddy) in between the two layers. This is usually done in closed but well ventilated rooms or godowns. Singh and Mathur (1952) have reported that a temperature of 19·4 to 21·1 °C, during ripening, is congenial to development of high TSS, reduced acidity and in improving ascorbic acid retention.

Various kinds of ripening material in the form of leaves and sawdust have been tried for ripening mangoes, viz., leaves of *Albizzia lebbeck*, *Butea frondosa*, mango, banana and sugarcane (Singh, 1978). Storage in sawdust, *Albizzia lebbeck* leaves and mongo leaves resulted in better ripening and fruit quality.

Other methods of ripening are all artificial, utilising special chemicals or exposure to gases like acetylene and ethylene. These do improve fruit colour but the fruit quality is impaired because of the general tendency to ripen immature fruits to catch an early market and to make more profit. In general, it may be stated that the fruits ripened under room condition (open) contain more ascorbic

acid whereas the carbide treated fruits have the least amount at all stages of maturity (Singh, 1978).

5.17 Marketing

The usual practice is to auction the orchard to contractors at the flowering stage itself. The contractors are quite often financed by the commission agents or they themselves send their produce to leading commission agents through forwarding agents. Also, quite often, the original contractor passes on the orchard to subcontractors and makes some money in the process. This chain of middlemen eats away the legimate profits of the growers and makes enormous money at their cost as well as the consumers. Also, the orchards are not looked after well. Consequently, such plantations become less remunerative and unproductive in due course of time. Another evil of the contract system is the immature harvesting of fruits. The prevailing system, centred around the contractor, is disastrous to the growers as well as the consumers.

Cooperative channels of marketing would have been the ideal solution but these are still confined to few areas in Gujarat (Bulsar), Maharashtra (Vengurla, Malva and Deogarh), Tamil Nadu and Andhra Pradesh. There are only 2 growers' associations in Bihar, one in Mysore and none in Uttar Pradesh -- the premier mango growing state in the country (Singh, 1978).

5.18 Breeding and Varietal Improvement

Despite an enormous wealth of mango varieties available in the country, an ideal variety of mango is still lacking. Most of the present-day varieties appear to have been selected for characters like fruit size and quality, and period of maturity. Some of the more important characters like precocity, dwarfness, prolificity and regularity of bearing, self-fruitfulness, and resistance to pests and diseases remained unselected. These characters are now of vital importance for making the best use of our shrinking land resources, reducing the cost of cultivation and for improving the productivity per unit area. However, combining all the desirable characters in a single variety is difficult, if not impossible, since the mango is a highly heterozygous crop of suspected allopolyploid origin. An ideal variety can, therefore, be built only in stages.

Inter-varietal hybridisation

Attempts to develop improved varieties of mango through breeding are underway since almost the beginning of the present century. Burns and

Prayag (1921) were the pioneers in initiating such work in 1911 at Pune. Subsequently, breeding work was undertaken at Sabour in Bihar (Sen *et al*, 1946 ; Roy *et al*, 1956), Kodur and Hyderabad in Andhra Pradesh (Naik, 1948 ; Bhujanga Rao and Rangacharlu, 1958 ; Swamy *et al*, 1970), Saharanpur in Uttar Pradesh (Singh, 1957 ; Singh, 1963), Krishnagar in West Bengal (Mukherjee *et al*, 1961), Qaidian in the Punjab (Jawanda and Singh, 1963) and at the IARI, where it was initiated in 1961 (Singh *et al*, 1977).

The work at Sabour yielded two promising hybrids, viz., Mahmud Bahar and Prova Sankar about which nothing was heard subsequently. Same is more or less true of the hybrids evolved at Kodur, viz., Neluddin, Swarna Jehangir, Neelgoa and Neeleshan.

The progress made so far cannot be termed as satisfactory. This applies to the mango breeding work done elsewhere as well (Singh, 1960 ; Sturrock, 1977). However, it is quite understandable in a crop like mango which is highly heterozygous and endowed with a long juvenile phase. In such a crop, breeding work is necessarily laborious, and at times even frustrating, and requires sustained effort over a number of years. Some other major contributing factors are lack of well-defined objectives, improper choice of parents, cumbersome and laborious techniques of hybridisation, and meagre hybrid populations available for selection. This is amply illustrated by the success achieved at the IARI where, taking care of all these points, two improved varieties (Mallika and Amrapali) could be evolved and released for the growers although the hybridisation work was initiated as late as 1961.

Other major landmarks in the field of mango breeding, besides the release of the two varieties and the discovery of self-incompatibility, are (i) development of improved and more efficient techniques of hybridisation, (ii) gaining some knowledge about the inheritance pattern prevailing in mango and (iii) development of sound preselection criteria.

Improved techniques of hybridisation

In the early days, during 1911-60, large-sized muslin bags having 2-3 iron rings were utilised in the hybridisation programme (Sen *et al*, 1946). These were cumbersome in handling since each panicle enclosed in a bag was to be opened and closed everyday during the flowering period for making pollinations and fewer panicles could be handled in the short flowering period. Also, the number of flowers pollinated on a single panicle was rather too high because the same few panicles were utilised for a number of days ; the number of flowers pollinated on a single panicle running into hundreds. This appears to be highly unnatural as it is rather impossible to imagine a variety of mango which could, on an average, bear more than one fruit per panicle. This technique was wasteful since the outcome was, by any standards, meagre.

In view of these difficulties, improvements were brought about to increase the efficiency of the mango hybridisation work. Emphasis was, therefore, laid on utilising a larger number of panicles and pollinating few flowers per panicle (Mukherjee *et al*. 1961). The conventional muslin bags have now been replaced by light (100 gauge thickness) small-sized polythene bags which are finely perforated before use. With this technique, the efficiency of mango hybridisation has been improved considerably.

Since 1961, about 82,000 crosses have been made at the IARI and these have yielded 1252 hybrids. This is much larger a population of mango hybrids, even if one pools the number of hybrids raised at all the other mango research centres in India (Singh *et al*, 1977, 1981).

The discovery of self-incompatibility, in some of the most popular varieties of mango, led to the standardisation of the caging technique in which pollination is effected through houseflies, thus doing away with the necessity of hand pollination (Sharma *et al*, 1972).

More recently, a study based on a genetic 'marker' (dominant purple colour of the new leaves and inflorescence, and the dominant beak of the var. Totapari Red Small, over that of the var. Dashehari), has shown that the percentage fruit set from the crosses in mango can be doubled simply by doing away with the process of bagging the panicles again after cross-pollination by hand (Singh *et al*, 1980). The increased fruit set is largely due to preventing the stigmatic and stylar injury to the pollinated flowers, which is otherwise a common occurrence. The time saved by avoiding rebagging of the pollinated panicles can be utilised in handling larger number of panicles in the short span of flowering.

Inheritance pattern in mango

Information on this aspect was not available until recently. An insight has now been obtained into the inheritance of some characters like tree habit, juvenility, regularity of bearing and fruit quality, fruit size, fruiting in bunches, fruit beak, colour of the new leaves and panicles, leaf flavour, etc. Observations have shown that some of the more desired characters like dwarf tree habit, precocity and regularity of bearing are governed by recessive genes (Majumder *et al*, 1972 b ; Sharma *et al*, 1972).

The regular bearing varieties like Neelum, Bangalora and Totapari Red Small were found to have the characteristic of putting forth new growth flushes just after harvesting of fruits or even earlier. These newly emerged shoots are able to flower and fruit in the succeeding season.

Studies have also established that amongst the regular bearing varieties, only the Neelum happens to be the best combiner. The regularity of bearing of the varieties Totapari Red Small and Bangalora appears to be closely linked with their inferior fruit quality (Singh *et al*, 1981). Likewise, the variety Bhadauran,

which has fruits of poor quality but is the only known variety to be free from floral malformation, holds little promise for evolving good quality mango which may also have resistance to malformation.

The studies conducted at the IARI have established that for involving any variety in the hybridisation programme for transferring a particular desirable character in the hybrids, it must also have at least an acceptable fruit quality.

Pre-selection criteria

In a long-lived perennial, having a long pre-bearing age, it is advantageous to identify certain characters which may facilitate a quicker selection of the desired types amongst the hybrid population. This can save precious time, land and labour.

Some pre-selection criteria, which could give a precise indication of the fruit quality, bearing habit and growth habit have now been identified at the IARI. Leaf flavour has direct correlation with the fruit flavour (Majumder *et al*, 1972 b). Emergence of new growth flushes, simultaneously with fruiting or immediately after harvest, is indicative of regularity of bearing (Sharma *et al*, 1972). Likewise, a lower stomatal density per unit area is indicative of dwarfness (Majumder *et al*, 1981).

Induction of mutations

A plant breeder's approach towards finding the solutions for major problems in a crop is largely centered around creation of a wide genetic variability and its exploitation, besides collection and screening of the existing germplasm. This variability could be inducted in two ways—(i) through conventional hybridisation (which has been dealt with earlier) and (ii) by inducing mutations through physical and chemical mutagens (Broertjes and Van Harten, 1978).

Although the traditional mango varieties, individually, do possess one desirable character or the other, varieties having more of the desirable characters are lacking. Mutation breeding, with a few exceptions in crops like apple, apricot, cherry and peach (Broertjes, 1977), has not been given a fair trial by the fruit breeders in general, and in mango, in particular. In the case of mango only a solitary attempt, using a few bud sticks, has been made (Siddiqui *et al*, 1966) and this too has, probably, not been pursued further.

The main advantages of mutation breeding are, that the basic genotype of the variety is usually only slightly altered (as compared to hybridisation of two different varieties), while the improved character(s) is (are) added, and the time required to breed an improved variety can be much reduced than when hybridisation is employed to achieve the same objectives (Sigurbjornsson, 1970).

The work on induction of mutations was, therefore, initiated at the IARI in 1972 with a view to developing dwarf, regular-bearing, self-fruitful and disease-resistant mutants having good fruit quality. This work has led to the

standardisation of effective dosages of some of the mutagens and also in the standardisation of the propagation technique for the mutagen-treated bud-sticks (Sharma *et al*, 1981).

It has been observed that dosages of γ-irradiation, beyond 5 kR are lethal to mango. The LD_{50} for different varieties ranges between 2 and 4 kR ; being 3·9 for Neelum, 2·9 for Dashehari and 2·4 for Mallika. This suggested that newer a variety, greater is its radiation sensitivity. The effective dosages of EMS (var. Dashehari) and NMU (var. Neelum) were found to be 1·50 per cent and 0·05 per cent, respectively. Another interesting point that emerged is that the spectrum of changes induced was more or less the same, by both physical and chemical mutagens.

Some very interesting plant types have been obtained in the vM_1 generation by stabilising the changes induced through the heading back technique (Sharma *et al*, 1981). Amongst these are plants with very long and very short extension growths, very thick and very thin shoots , multiple branching shoots ; very large and very small lanceolate leaves, and small leaves with highly wavy margins ; and plants which appear to be compact in growth habit. A few of these induced plant types, both from the varieties Dashehari and Mallika, appear to be promising from the point of view of dwarfness and, hence, may prove their immense value. Higher TSS and better sugar/acid blend, than the standard Dashehari (control), were also observed in few plants.

Future breeding programme

Despite the significant advances made in this area, much remains to be done in regard to developing varieties suited to different regions and differing needs, viz., for the export trade and for the processing industry for various products. Improved varieties, having resistance against some of the more serious diseases and pests are needed to cut down the extra cost and labour required for checking them through chemical sprays which are, above all, hazardous too.

However, such a breeding programme can be effectively inplemented only by widening the germplasm base by collecting all the *Mangifera* spp., varieties and promising wild types at 2-3 major mango research centres in the country. This is essential for studying their characteristics, which could be usefully transferred to the new varieties through hybridsation.

However, till now, no attention has been paid to this fundamental aspect and before long many of the species and wild relatives of mango may become extinct in the developing countries of south Asia (where these largely exist in wild state) under the pressure of population explosion and rapid industrialisation.

Recently, one such race has been located by Sharma and Sen Choudhury (1976) in the forests of southern Tripura. Though its fruits are very small in size, it has the habit of bearing in bunches of up to 50 fruits per panicle. The trees were apparently very healthy and free from malformation. The leaf size is

perhaps the largest ever recorded in the genus *Mangifera* and the other leaf characters also do not tally with any of the species or wild types described so far. The north-eastern states, bordering Burma and Bangladesh, offer vast scope in this regard since this happens to be the area where the mango originated.

The chromosomal studies conducted thus far in five of the 41 species of *Mangifera* (viz., *M. indica*, *M. sylvatica*, *M. caloneura*, *M. odorata* and *M. zeylanica*) have shown that these species have the same chromosome number ($2n=40$) and may inter-cross easily (Mukherjee, 1963). Some of their useful genes can possibly be transferred to mango. The only exception reported in the literature so far is that of the var. Vellai Collumban which was reported to be a tetraploid, viz., $2n=80$ (Roy and Visweswariya, 1951). This variety was, therefore, studied by Sharma *et al*. (1976) with a view to developing triploids and aneuploid series in mango. However, its cytology revealed it to be a mere diploid, like any other variety of mango.

Nevertheless, some scope does appear to exist for developing haploids through culturing of anther/endosperm or meristem, where chromosomal variations are likely to occur. Such studies will lead to a better understanding of the origin and inheritance of characters in mango, besides helping in the development of triploids, trisomic and tetrasomic which may be of immense academic and applied value. Studies of this nature have not been undertaken in tree fruits, excepting guava where useful aneuploids have been isolated by crossing triploid with diploid guava (Majumder and Mukherjee, 1972).

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6

BANANA

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Banana is one of the oldest cultivated tropical fruits in India. According to some pomologists the fruit that tempted Eve was banana not apple and the leaf to cover her modesty was the leaf of banana not fig. Banana is the second important fruit next to mango in India. The crop is not seasonal in nature like many other fruit crops and is available in large quantity throughout the year.

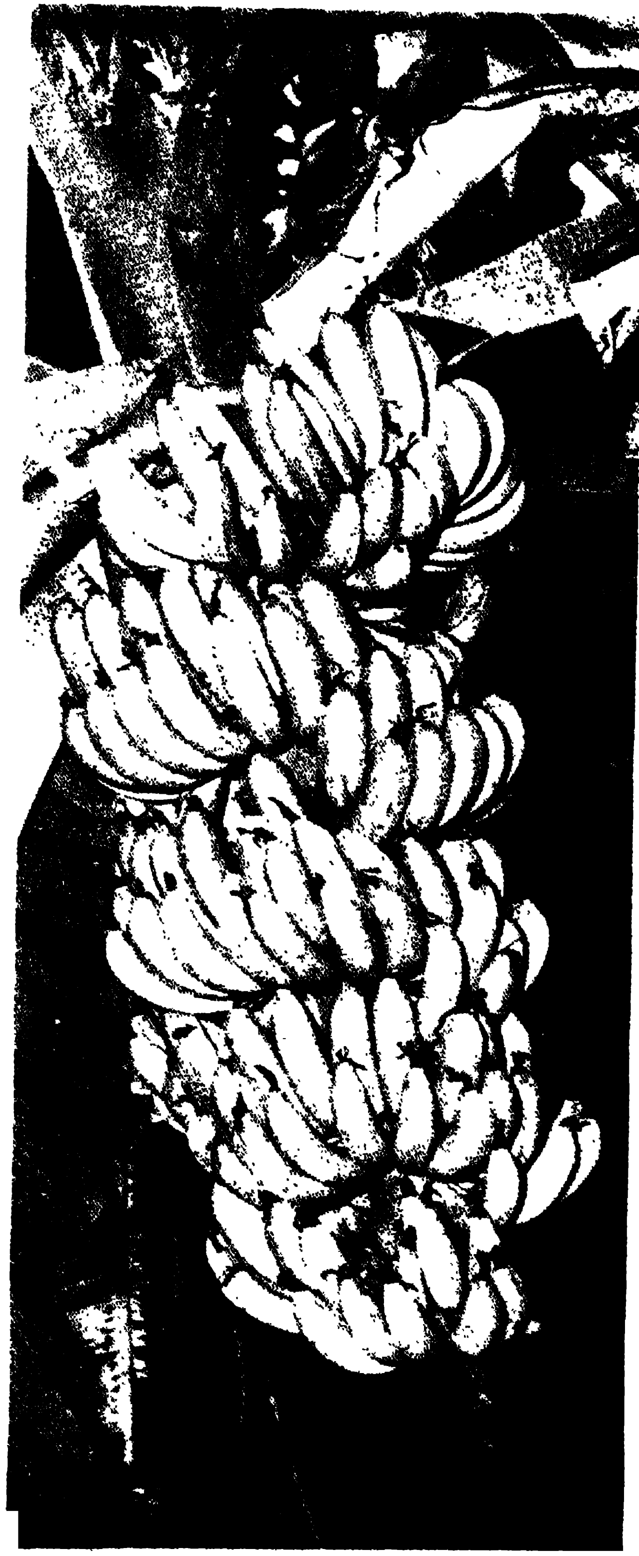
6.1 Composition and Uses

Banana is the cheapest, plentiful and most nourishing of all fruits. It contains nearly all the essential nutrients including minerals and vitamins and has several medicinal properties. Banana is a rich source of energy. About 24 bananas each weighing around 100 gm would provide the energy requirement (2400 cal/day) of a sedentary man. The composition of the fruit is given below (Anon, 1976).

Moisture	70·0 per cent	Phosphorus	290·0 ppm
Carbohydrate	27·0 per cent	Calcium	80·0 ppm
Crude fibre	0·5 per cent	Iron	6·0 ppm
Protein	1·2 per cent	β- carotene	0·5 ppm
Fat	0·3 per cent	Riboflavin	0·5 ppm
Ash	0·9 per cent	Niacin	7·0 ppm
		Ascorbic acid	120·0 ppm

All parts of this plant are useful. In Kerala a number of varieties are used as a baby food. Paper board, tissue paper, etc., can be prepared out of banana pseudostem. Various products like banana chip, banana fig, soft drink, flour and powder, jam, confections, dehydration of core slice, etc., can be made from banana.

In Uganda and parts of Tanzania large quantities of beer are made from banana. Simmonds (1966) stated that about half the bananas of the world are eaten raw and ripe, about half are eaten as cooked vegetable. It is one of the biggest single trade items in international fruit trade.



A bunch of
var. Giant Governor

Bunchy top infected plant

eaf-spot disease

6.2 Origin and Distribution

The edible banana is believed to have originated in the hot, tropical regions of South-East Asia (Spiden, 1926 and Sauer, 1952). India is believed to be one of the centres of origin of banana. Its cultivation is distributed throughout the warmer countries and is confined to regions between 30°N and 30°S of the equator. The important countries that cultivate banana are given in Table 1 (Tai., 1977).

TABLE 1. LIST OF COUNTRIES GROWING > 100000 ha

Country	Area (ha)
Asia	
India	270000
Philippines	217000
Thailand	198000
Africa	
Uganda	464000
Zaire	263000
Tanzania	189000
Ivory Coast	187000
Burundi	127000
Kenya	121000
South America	
Colombia	728000
Brazil	273000
Ecuador	179000
Venezuela	115000

Banana is also grown in many other countries of the world namely Bangladesh, the Carribbean Islands, the Canary Islands, Florida, Egypt, Israel, Ghana, Congo, South Africa, Fiji, Hawaii, Taiwan, Indonesia, the Phillippines, South China, Queensland, Sri Lanka. The greatest acreage of bananas is in Africa, where bananas reach their maximum importance as starchy food. They are the staple food of the Buganda in Uganda, the Wahaya in Bukoba and the Wachagga in Tanzania.

6.3 Species and Varieties

Species

The banana belongs to the family Musaceae. There are only two genera, viz., *Ensete* Horan. and *Musa* L. with about 50 species in this family. Ensete in an

old declining genus which probably originated in Asia and spread to Africa, has about 6-7 species, of which *E. ventricosa* Cheesm. is reported to be grown in Ethiopia as a food crop. A brief account of the genus *Musa* as given by Purseglove (1975) is presented below :

Musa L. ($X=10, 11$; rarely 7 or 9)

About 40 species of perennial, stooling or rhizomatous herbs in south-eastern Asia and the Pacific, with their centre of diversity and probably of origin in the Assam-Burma-Thailand area. They are mainly plants of the lowland tropics, requiring high temperature, high humidity and high light intensity ; they are intolerant of root competition, particularly from grasses, poor drainage and drought.

Pseudostems composed of tightly clasping leaf sheaths, slightly swollen at base ; suckers freely produced ; bracts and flowers inserted independently on peduncle, commonly deciduous by abscission, except for functionally female ovaries in basal hands ; basal flowers generally female only ; male flowers on distal hands ; bracts usually reddish, purple or violet due to anthocyanins ; pollen grains with finely granular surface ; seeds 7 mm or less in diameter.

The genus is divided into the following five sections :

(i) **Eumusa** : ($X=11$; $2n=22$ in wild spp., 22, 33, 44 in varieties.)

The largest section with 13-15 species, pseudostems usually exceed 3 m in height ; inflorescences pendent or semi-pendent : bracts usually dull in colour ; flowers many, in two series in each bract.

The edible cultivated parthenocarpic bananas, except for the Fe'i bananas belong to this section which are derived from *M. acuminata* Colla and interspecific crosses with this species and *M. balbisiana* Colla. *M. basjoo* Sieb in Japan yields fibre, which may be made into textiles.

(ii) **Rhodochlamys** : ($X=11$; $2n=22$) 5-7 spp. from India to Indonesia.

Pseudostem less than 3 m high ; inflorescence erect ; flowers few to a bract, usually in a single series ; parthenocarpy absent. *M. ornata* and *M. velutina* are sometimes grown as ornamental plants.

(iii) **Callimusa** ($X=10$; $2n=20$) 5-6 spp. in Indo-China, Malaya and Borneo.

Plants of small stature ; usually with erect inflorescences and purplish bracts ; parthenocarpy absent. *M. coccinea* is grown as an ornamental plant.

(iv) **Australimusa** : ($X=10$; $2n=20$) 5-7 spp. from Queensland to the Philippines.

Inflorescence pendent, semi-pendent or erect. Included here are *M. textilis*, abaca or Manila hemp, and the Fe'i bananas are still gathered and eaten in the Polynesian islands after cooking, but are not as important as they were formerly. Fe'i banana is some times reffered to the sp. *M. fehi* Bert. ex. Vieill and is related

to *M. maclayi*. Their fruits are parthenocarpic and predominantly female sterile ; the fruiting bunch is erect and contains a red sap : the skin is orange in colour when ripe and the flesh is yellow.

(v) **Incertae sedis** : There are a few species of doubtful affinity. These include *M. ingens* ($X=7$: $2n=14$) which was discovered in New Guinea, grows to a height of over 10 m and is the largest herb known and *M. beccarii* ($X=9$; $2n=18$) from North Borneo.

Several Latin names have been used till recently in the botanical nomenclature of the banana. Three of the earliest employed were *Musa paradisica* L., *M. cavendishii* Lambert and *M. sapientum* L. These are no longer favoured and have been superseded by a genome nomenclature for varieties in recognition of their derivation from two wild species : *Musa acuminata* and *Musa balbisiana*. Edible bananas have 22, 33 or 44 chromosomes : the basic number being $n=11$ so that these varieties are respectively diploid, triploid and tetraploid. Triploid cultivars are generally the most numerous, diploid somewhat less and tetraploid forms are very rare.

Simmonds and Shepherd (1955) devised a method of indicating the relative contributions of these two wild species to the constitution of any variety through a scoring technique of certain morphological characters and applying the derived information for distinguishing the *M. acuminata* types from those of *M. balbisiana*. Depending upon the contribution of these parents to the constitution of the progeny and combining their chromosomal status, the naturally occurring edible bananas fall into six groups : two diploids, three triploids and one tetraploid.

On analogy with *Triticum* and *Gossypium*, the notion of 'genome' was suggested by Simmonds and Shepherd (1955) as a key to the classification. When A represents the genome with 11 chromosomes from *M. acuminata* and B represents the genome with 11 chromosomes from *M. balbisiana*, then the group of edible bananas can be divided as given in Table 2. As regards nomenclature, Simmonds (1960) suggested that formal reference to a variety may be made in the manner of the examples given in the same Table. A list of wild and important varieties of banana in India is given in Table 3 (Bakthavatsalu and Sathiamoorthy, 1979).

The best known bananas of commerce all over the world belong to the pure *acuminata* AAA group, but the *balbisiana* genome is associated with greater drought hardiness and resistance to disease. It is not surprising, therefore, that hybrids of AB, AAB and ABB constitution are better adapted to monsoon areas with marked dry seasons ; these bananas show wide variability and are grown chiefly for local consumption in India and Uganda. The AA and AAA bananas are cultivated mainly in areas where rainfall is equally distributed throughout the year or where water for irrigation is readily available : the greater uniformity of the AAA types makes them particularly suitable for large scale production for export as in Central America, the Caribbean islands, and northern South America.

TABLE 2. GENOMIC CLASSIFICATION AND NOMENCLATURE OF BANANA

Ploidy	Score	Constitution	Nomenclature (examples)
2x	16–23	AA	*Musa* (AA Group) 'Matti'
3x	15–21	AAA	*Musa* (AAA Group) 'Gros Michel'
			Musa (AAA Group, Cavendish subgroup) 'Robusta'
4x	15–20	AAAA*	*Musa* (AAAA Group) 'Bodles Altafort'
2x	46–49	AB	*Musa* (AB Group) 'Ney Poovan'
3x	26–46	AAB	*Musa* (AAB Group) 'Champa'
	59–63	ABB	*Musa* (ABB Group) 'Kancha Kela'
4x	63–69	ABBB	*Musa* (ABBB Group) 'Klue teparod'

* Not encountered in nature. Bodles Altafort is a synthetic hybrid evolved in the West Indies.

TABLE 3. LIST OF WILD BANANAS AND IMPORTANT VARIETIES IN INDIA

Name	Synonym	Mutant
WILD BANANA		
1. *Musa acuminata* subsp. *burmannica* (S)		
2. *Musa balbisiana* (S, NE)		
3. *Musa laterita* (S)		
4. *Musa ochracea* (W)		
CLONE		
AA Group		
1. Anaikomban (S)	Aaattukomban (S)	Ambalakadali (S)
2. Matti (S)		Erachi Vazhai (S)
3. Sanna chenkadali (S)		
4. Kadali (S)	Nivedyakadali (S)	
5. Namarai (S)		
6. Pisang lilin		
7. Tongat		
AB Group		
1. Ney Poovan (S)	Safed velchi (W) Elakki bale (S) Chini champa (NE)	
2. Kunnan (S)		
3. Nattu Poovan (S)		

E—East, NE—North-East, S—South, SE—South-East, W—West.

Name	Synonym	Mutant
AAA Group		
1. Gros Michel		High gate
2. Amritsagar (NE)		
3. Dwarf Cavendish	Pacha Vazhai (S) Mauritius (S) Basrai (W) Jahaji (NE) Kabulee (NE)	
4. Giant Cavendish	Bongali Jahaji (NE)	
5. Robusta	Peddapacharati (S) Harichal (W)	
6. Pisang masak hijau	Lacatan	
7. Wather (NE)	Digjoa (NE) Naga bale (W) Kommu arati (S) Mohan tansi (E)	
8. Chenkadali (S)	Red Lalkel (W) Agniswar (NE)	Venkadali (S) (Green red)
9. Chakkrakeli (S)	Honda (NE) Raja Vazhai (S) Raja bale (S) Thaen kadali (S)	
AAB Group		
1. Poovan (S)	Karpura chakkrakeli (S) Lalvelchi (W) Champa (NE) (Mysore)	Motta poovan (S)
2. Rasthali (S)	Amirthapani (S) Sonkel (W) Mutheli (W) Rasabale (S) Malbhog (NE) Morthaman (NE) (Silk)	Ayiranka rasthali (S)
3. Pachanadan (S)	Kaali (S) Laadan (S) Galibale (W) Saldatti (W)	
4. Nendrapadathi	Saker champa (NE)	

Name	Synonym	Mutant
5. Rajapuri	Walha (W) Kullan (S)	
6. Virupakshi (S)	Mala Vazhai (S) Sirumalai (S) Vannan (S) (Pome)	Krishna Vazhai (S) (Black stemmed) Ney Vazhai (S) (Red stemmed)
7. Nendran (S)	Rajeli (W) (French plantain)	Eleri (S) (Green French Plantain) Velathan (S) (Wine Plantain) Karu Nendran (S) (Black French Plantain) Anil Vazhai (S) (Variegated French Plantain)
8. Chinali (S)	Pisang rajah	
ABB Group		
1. Nalla bontha (S)	Monthan (S) Bankel (W) Khasadia (W) (Bluggoe)	Thella bontha (S) Syn. Silver Bluggoe Sambal monthan (S) Nalla bontha bathees (S)
2. Monthan (S)	Pidimonthan (S) Kachkola (NE) Jatikol (NE) Dhussray (NE) Bhos (NE)	Pacha montha bathees (S) Sambarani monthan (S) Booditha montha bathees (S)
3. Kuribontha (S)	Chakkia (NE) Muthia (NE)	
4. Peyan (S)	Peyladan (S) Poothibale (S) Bhurkel (W)	
5. Karupuravalli	Peykunnan (S) Manohar (N) Sail kola (NE) Kostha bontha (S) (Pisang awak)	
AAAA Group		
1. Bodles Altafort		
ABBB Group		
1. Klue teparod		

Varieties

In India, more than 300 varieties are recorded. However, a particular variety is known by more than one name in different places and the actual number may be about 70. The important banana varieties grown in India are described below :

Poovan (Tamil Nadu) : Musa (AAB) group—Syn. Champa (West Bengal), Lalvelchi (Maharashtra), Karpura Chakkrakeli (Andhra Pradesh), Palayangodan (Kerala), Kadali (Tamil Nadu), Dora Vazhai (Nilgiris), Bangalow Vazhai (Tamil Nadu), Fill basket or Mysore (Trinidad), Chini Champa. This is an important table variety of West Bengal, Tamil Nadu and Kerala.

The plant is tall, hardy and grows vigorously under the ratooning system of cultivation. It is a true cosmopolitan variety growing with equal vigour both in India and the West Indies. One of the distinguishing characters of the plant is the rose pink colour of the outer side of the midrib. It can grow under unirrigated condition or with scanty irrigation. The fruit is medium to small, yellow skinned, firm fleshed with a subacid taste. It has a good keeping quality. It is resistant to Panama wilt and fairly resistant to bunchy top disease. The average bunch weight is about 15 kg.

Kanchkela (West Bengal) : Musa ABB group—Syn. Monthan (Tamil Nadu) Bontha (Andhra Pradesh), Madhuranga Bale, Aunda Bale, Mangakai (Karnataka), Khasdi, Banket (Maharashtra), Bainsa (Bihar), Ponthan (Kerala) Thezhuthani (Wyannad), Batisa (Orissa), Bluggoe (Trinidad), Pisang Nanka (Malaysia).

This is the most important commercial culinary banana variety of India. The plant is tall, robust, light green, very hardy and grows under unirrigated condition. Average bunch weight is about 15 kg. In Tamil Nadu, the ripe fruit is also popular.

Dwarf Cavendish : Musa (AAA) group—Syn. Basrai, Loton (Maharashtra), Kabuli (West Bengal), Vaman Keli, Bhusaval (Andhra Pradesh), Pacha Vazhai, Mauritius, Kuzhi Vazhai (Tamil Nadu), Jahaji, Hirvi.

It is the leading commercial variety of Maharashtra. The plant is dwarf, fruits large, curved, skin thick and greenish, flesh soft and sweet. The greenish colour of the fruit is retained to some extent even after ripening but fruits ripened during the winter season develop yellow colour. It is susceptible to bunchy top and leaf spot disease but resistant to Panama wilt. The keeping quality of fruit is, however, not good. A bunch on an average weighs about 20 kg.

The Dwarf Cavendish is an important banana in international trade. Two semi-tall mutants, Monsmari and Williams Hybrid are widely grown in Queensland. Lacatan, a tall form has assumed commercial status in the Caribbean Islands, gradually replacing Gros Michel. The dwarf banana covers a large area in the Canary Islands (Canary banana), African mainland, tropical America, the islands of the Pacific and Indian Oceans, South China and Israel.

Harichal : Musa (AAA) group—Syn. Bombay green (Maharashtra), Pedda-pachaarati (Andhra Pradesh), Robusta (Tamil Nadu). It is a semi-tall sport of Dwarf Cavendish. It is another important commercial banana of Maharashtra. Fruits large, skin thick, greenish to dull yellow, sweet and delicious. The fruits have better keeping quality than that of Dwarf Cavendish. Average bunch weight is 20 kg.

Martaman (West Bengal) : Musa (AAB) group—Syn. Rasthali (Tamil Nadu), Mutheli (Maharashtra), Malbhog (Bihar), Amruthapani (Andhra Pradesh), Rasabale (Karnataka), Sonkel (Kerala), Silkfig (Trinidad).

It is the choicest table variety of West Bengal. The plant is tall and can be identified by the yellowish-green stem with brownish blotches, reddish margins of the petiole and leaf sheath. The average bunch weight is about 12 kg. Fruits are medium-sized and similar to that of Poovan in appearance, skin thin, ivory yellow in colour, flesh firm, sweet with a pleasant aroma. Its cultivation is decreasing due to susceptibility to Panama wilt. The other demerits are easy dropping of ripe fruits from the bunch and formation of hard lumps in the pulp.

Hill Banana : Musa (AAB) group—Virupakshi Syn. Mala vazhai. The hill bananas are a speciality of Tamil Nadu. These are perennial bananas of high quality. There are two main types : Sirumalai and Virupakshi. Fruits of Sirumalai have better taste compared to Virupakshi. The average bunch weight is about 12 kg.

Nendran (Kerala) : Musa (AAB) group Syn. Ethakai (Kerala), Rajeli (Maharashtra), Kochikehel (Sri Lanka), Plantain (Trinidad). This variety is known in all parts of the world as plantain. This is a dual purpose variety of Kerala. It has very good keeping quality. The fruit is relatively longer and thicker than most other bananas. The bunch is not compact. The average bunch weight is 15 kg.

Safed Velchi : Musa (AB) group—Syn. Sonery (Maharashtra) Ney Poovan (Tamil Nadu), Nitka Bale, Deva Bale (Karnataka), Kadali (Malabar), Nhali Poovan (Kerala). It is under stray cultivation throughout South India and Maharashtra and mostly grown as intercrop in coconut and arecanut garden. The plants are medium-sized with slender, yellowish pseudostem having reddish petiole margin. The fruits are small, firm-fleshed and sweet. The average bunch weight is about 12 kg.

Lalkela (Maharashtra) : Musa (AAA) group—Syn. Chenkadali, Sevazhai (Tamil Nadu), Anupan (Bihar), Rathambala (Sri Lanka), Red banana (Trinidad). The variety is grown throughout the world. The colour of the pseudostem, petiole, midrib and fruit peel is purplish red. The fruit is of good size and has a characteristic aroma. Average bunch weight is 20 kg.

Kunnan (Kerala) : Musa (AB) group—Syn. Jirige Bale (Karnataka), Patti Mokiri (Orissa). This is a quality variety of Kerala. The plants are medium-sized and slender. Fruits with firm pulp taste well.

Amritsagar (West Bengal) : Musa (AAB) group. This is one of the choicest varieties of India. Plants are delicate in nature and average bunch weight is quite poor. Fruits are good-sized and the pulp has a good taste.

Chakkrakeli (Andhra Pradesh) : Musa (AAB) group—Syn. Raja bale (Karnataka). Thaen kadali (Tamil Nadu), Chakkrakadali (Kerala). The plants are slender and medium-sized with petiole borders open and conspicuously red. The fruit is curved, thick-skinned, yellowish pulp, juicy and very tasty.

Gros Michel : Musa (AAA) group –Syn. Martinique Fig, Jamaican banana (America, England, the Caribbean Islands), Blue Field (Hawaii), Anamalu (Sri Lanka). Among the dessert banana varieties of the world, Gros Michel occupied the first rank in desirable fruit characters such as size, quality, flavour, attractive skin colour, resistance to bruising, grade yield, symmetry and strength of bunch. The most serious demerit of this variety is its susceptibility to wilt.

Giant Governor : Musa (AAA) group—Cultivation of this variety is gaining popularity in West Bengal. The plant is medium-dwarf, fruits large, greenish to dull yellow in colour, flesh firm and sweet. A bunch on an average weighs about 15 kg. The variety is susceptible to leaf spot (sigatoka) but resistant to wilt.

Besides the above varieties, there are a number of other varieties of importance in particular localities and they are as follows :

Pacha Nadan (South India), Mannan (Kerala), Peyan (Tamil Nadu), Chingan (Kerala), Anaikomban (Andhra Pradesh and Tamil Nadu), Alshi (Maharashtra), Hazare (Maharashtra), Amebili (Maharashtra), Kanthali (West Bengal).

6.4 Soil and Climate

Soil

Banana can be grown in almost all types of soils in India provided adequate soil moisture is available. Deep, well drained, friable loamy soil with adequate organic matter is ideal for its cultivation. Banana is one of the few fruits which has a restricted root zone. Therefore, depth and drainage are the two most important considerations in selecting the soil for banana. It can grow well in slightly alkaline soils, but saline soils with salinity exceeding 0·05 per cent are unsuitable. In alkaline soils wilt disease is less prevalent.

Commercial crops of banana in India are being raised on the heavy clay soil of the Cauveri delta and over large tracts of the Gangetic delta with alluvial soils. Extensive sandy tracts of the Basin area and large areas of black loam in Maharashtra are also famous for growing good crop of banana. The coastal sandy loams as well as the red lateritic soil of the hilly tracts of Kerala also yield good crop.

Climate

The banana is basically a plant of the humid tropics, but is adapted to a wide range of climatic conditions ranging from wet tropical to dry subtropical. It can be grown from sea level to an altitude of 1200 metres. It grows well to a temperature range between 10 and 40°C. The major effects of unfavourable weather conditions are the breakage or uprooting of pseudostem by storm, and cyclones, reduction in plant growth and malformation of bunches due to low temperature, etc. Frost is a limiting factor for successful cultivation of banana. In cooler climate the crop requires longer time to mature. Hot winds blowing in high speed during the summer months shred and desiccate the leaves. On an average, 100 mm rainfall per month appears to be satisfactory for growth of banana. Stagnation of water is injurious and may cause diseases like Panama wilt.

6.5 Area and Production

There are three important banana producing zones in India—South India, Western India and Eastern India. The area and production of banana in different states in India according to Dass (1980) are given below :

TABLE 4. AREA AND PRODUCTION OF BANANA IN DIFFERENT STATES IN INDIA (1978-79)

State	Area in '000 ha	Production in '000 tonnes	Yield/ha in tonnes
Andhra Pradesh	18·1	264·9	14·63
Assam	21·7	280·1	12·90
Bihar	8·3	41·3	4·90
Gujarat	16·8	385·5	22·70
Karnataka	15·9	79·3	4·90
Kerala	50·1	615·4	12·20
Madhya Pradesh	7·9	154·5	19·50
Manipur	1·7	21·9	12·80
Meghalaya	2·9	38·0	13·10
Orissa	17·6	124·0	7·04
Tamil Nadu	58·9	1312·9	22·29
Tripura	2·8	18·0	6·42
Uttar Pradesh	0·6	2·4	4·00
West Bengal	11·5	100·7	9·15
Andaman and Nicobar Islands	0·9	3·0	4·00
Mizoram	0·7	3·9	5·50
Total	236·4	3445·8	14·6

The leading centres of banana production in the country are Tiruchirapalli, Malabar, the delta of the Cauveri, Tanjore, Salem and Palni Hills in South India, East Khandesh, Thana and Jalgaon in Maharashtra, North Kanara in Karnataka, Hajipur in North Bihar and Hooghly Nadia in West Bengal.

6.6 Propagation

In India, the material commonly used for planting is sucker. Sword suckers have a well-developed base with narrow sword-shaped leaf blades at the early stages. The second type is the water suckers with broad leaves, which do not produce a healthy banana clump. Planters throughout the world usually plant sturdy and healthy sword suckers. Other planting materials are peepers, whole or bits of rhizomes. In an experiment, Bartolome and Songchan (1962) compared three kinds of planting material (young suckers, old suckers and rhizomes) of varieties Saba and Latundant and found no significant variation in fruit yield or shooting capacity due to planting materials. Srivastava (1963) found that sword suckers were more vigorous, and produced bigger and heavier bunches in 11 months than the water suckers did in more than 15 months. Karikari and Arankwah (1977) also reported that sword suckers were the best planting material but poor in suckering. Bits were slow in growth whereas large suckers of all types were generally better planting material than medium and small ones. Four-month-old suckers and split rhizomes (each weighing 2 kg) produced heavier bunches compared to those obtained from peepers (Chattopadhyay *et al*, 1980).

Whole or split rhizomes can also be used when suckers are not available. Bits of rhizome may be planted in the nursery for sprouting. Souza *et al.*, (1974) recommended whole and half rhizomes as planting materials in Brazil. Bhan and Majumder (1956) concluded that butts and bits were equally good planting material. Therefore, for quick multiplication of a variety rhizome bits may be used, though the plants will require little longer time to fruit.

Recently, multiplication of virus-free planting materials has been reported by Nadgauda *et al*, (1982) by tissue culture *in vitro*.

6.7 Cultivation

Season of planting

Planting time depends mainly on the climate and partly on economic factors. In many parts of India, the planting season starts with the commencement of south-west monsoon. Banana can be planted throughout the year except in severe winter and during heavy rains when the soil is very wet. Spring planting is the rule in subtropics. The planting is done in September-October in Malabar,

December in Travancore, February-March in the hill slopes of South India and in April on the banks of the Cauveri river. In the coastal area of Maharashtra planting is done in April, June, August or October. Kohli and Singh (1973) concluded that March planting of bits was superior to December planting. Chattopadhyay *et al*, (1980) recommended planting of banana between February and August in the Gangetic plains of West Bengal.

Preparation of land

The land should be deeply ploughed, harrowed and levelled properly. Pits of 0·6 m × 0·6 m × 0·6 m are dug sufficiently ahead at points fixed for planting.

Planting distance

Plant population per unit area depends on variety, topography, soil fertility, desuckering, various aspects of management, duration of plantation, etc. In general, tall varieties are given wider spacing than the dwarf ones. High density planting may be practised in monocrop culture, while wider spacing is advocated for ratoon crop.

A spacing of 9 feet (2·7 m) × 10 feet (3·0 m) for tall varieties and 6 feet (1·8 m) × 6 feet (1·8 m) for dwarf varieties were found most suitable (Bhan and Majumder, 1961). Sharma and Roy (1972) obtained the maximum profit in Dwarf Cavendish banana when spaced at 2 m × 2 m or 2·5 m × 2·5 m. Closer spacing also produced higher yield of fruits (Randhawa *et al.*, 1973). From a trial with Robusta banana spaced at 2·4 m × 1·8 m and 2·4 m × 2·4 m, the highest yield was obtained with a spacing 2·4 m × 1·8 m. Though there was higher yield in high density planting of growth was found to be slower and shooting was delayed. Finger tip disease was severe in close planting. In high density plantations nearly 30 per cent of the plants could not be harvested in time (Kohli *et al*, 1976). Patil *et al*, (1978) obtained 100 per cent increase in yield in Basrai banana when planted at a distance of 1·2 m × 1·2 m over a spacing of 2·0 m × 2·0 m. Chattopadhyay *et al*, (1981) recommended a plant density of 2500/ha for Giant Governor.

Irrigation

Water requirement of banana varies according to topography, soil, climate, variety and type of culture. If there is no rain, the plants should be irrigated immediately after planting. The soil in banana plantation should not be allowed to dry completely.

Banana is normally grown as a rainfed perennial crop in the western coast of India. In the hilly areas also no irrigation is given. In Bihar, irrigation is given every 10 days from December to June. In most inland areas, banana requires 40 to 50 irrigations from the time of planting to harvest. In north

Gujarat and east Khandesh even more may be required. In banana trenches are dug between alternate rows which serve to drain off excess water during the rains and later as irrigation channels. In West Bengal, during dry periods the plants are irrigated at an interval of 10 or 15 days. Tall varieties in West Bengal are grown under unirrigated condition or marginally irrigated condition while irrigation facility is a must to cultivate Cavendish banana. Jagirdar *et al.* (1963) conducted an experiment with Basrai banana adopting three spacings, three intervals between irrigations (6, 10, 14 days) and four levels of ammonium sulphate and concluded that plants given 100 lb (45 kg) N and irrigated at an interval of 6 days, produced mature fruits 83 days earlier than unfertilised plants irrigated at 14 days' interval. Trochoulias (1971) recorded increased yields over natural rainfall plots (average 1·52–1·78 m) by 117, 111, 84 and 5 per cent for the 90, 80, 60 and 30% available water capacity treatments respectively. Increased yield in banana through sprinkler irrigation in Cameroon was reported by Melin and Marseault (1972). Beneficial effects of irrigation were achieved by Trochoulias and Bensen (1973). From an irrigation experiment on the Valery banana in Honduras, Ghavami (1974) obtained significantly greater bunch weight at a rate of 44 mm water/week. He further recorded the highest fruit yield at a soil moisture tension of 30-40 centibars. Manica *et al.* (1975) irrigated Cavendish banana var. Nanicao when available soil water fell to 75, 50, 25 per cent along with no irrigation treatment as control. Number of hands and fruits/bunch and yield/ha increased linearly from no irrigation to 75 per cent. In Robusta banana lateral and vertical spread of root mass increased by decreasing the soil moisture (Krishnan and Shanmugavelu, 1980). In Israel, Lahav and Kalmer (1980) recorded that the usual commercial practice of applying 660 m^3 per 1000 m^2 at an interval of 3 days gave the maximum yield.

Manuring and fertilisation

Manuring should be done before planting in the pit for initiation of growth. Kohli *et al.* (1973) suggested to apply 20 kg of farm yard manure, 0·5 kg of dolomite and 225 kg of single super phosphate before planting. In wet lands, Madhava Rao (1974) recommended application of 15 tonnes of farm yard manure or compost in the pit before planting. He also reported that 7 kg compost and 112 gm sodium nitrate or ammonium sulphate are applied in the pit before planting Gros Michel banana at Jamaica.

The nutrient requirement of banana is very high. It is mainly exploited from a very limited soil depth due to shallow root system of the crop. The choice and dosages of nutrients to be applied depend on the variety, initial soil fertility, stage of plant growth, climate, etc.

Deficiency of nitrogen leads to slow growth, pale leaves, reduced rate of leaf production with smaller leaves, thin roots and reduced number of suckers. Excess nitrogen application results in delay in shooting, delayed maturity and

poor keeping quality of the fruits. Although, the phosphorus requirement of banana is less compared to nitrogen, it promotes strong root system healthy rhizome, favours fruit setting and accelerates ripening. Its deficiency causes poor growth, bad leaf colour and shrinkage of old leaves. Excess application of phosphorus results in curved hands. Potash deficiency causes premature yellowing of leaves, one or two leaves in the middle of the crown are affected and improper bunch filling is also a characteristic symptom of potash deficiency. Application of this mutrient increases the number of hands/bunch and finger size, improves fruit quality, develops resistance to diseases and reduces water uptake in banana.

Nutrient concentration in leaf is used to evaluate the nutrient status of banana. Hewitt (1955) established that nitrogen content was highest in the third youngest leaf; he chose the third leaf as standard for analysis and established the ranges and critical values ($N=2{\cdot}6$, $P_2O_5=0{\cdot}45$ and $K_2O=3{\cdot}3$ expressed as per cent of dry leaf) for leaf nutrients. Turner and Barkus (1981) reported recently, the results of an investigation on the nutrient concentrations in the leaves of 30 banana varieties. Chattopadhyaya (1981) also suggested that leaf nitrogen around 2·8, phosphorus 0·8 and potassium 3·8 per cent at the vegetative stage (6 months) are adequate for a high yield in banana variety Giant Governor.

Nitrogen should be applied in small doses at short intervals, while phosphorus at planting and potash in two split doses—one at planting and another at the time of initiation of flower. Summerville (1944) has made the following observations: (i) minerals should be abundantly available at the time of planting and at the time of initiation of ratoons, (ii) potash applied in the first two months has a greater influence on the number of hands produced than when applied after shooting, (iii) the uptake of phosphorus is more rapid when the plants are 2 to 3 months old, (iv) early stages are, therefore, critically important for application of nutrients and fertilisers, (v) the 3rd and 5th months are ideal for fertilisation and split applications more than three are most beneficial.

The subject on the nutrition of banana has been investigated extensively in different parts of the world. A detailed review by Twyford (1967) on the principles and practices of banana nutrition is available. Teaotia and Dubey (1971) conducted a study to test the performance of 5 sources of N, each at 3 levels on variety Harichal at Basti (UP) and concluded that diammonium phosphate was the best source and 180 gm N per plant produced the highest yield. In another experiment Teaotia *et al*, (1972) recorded maximum growth and yield by treatment with 75 hectare cm water and 300 gm ammonium sulphate, 600 gm superphosphate and 300 gm potassium sulphate per plant. The general recommendations on the nutrient requirement of banana in the different states of India as compiled by Shanmugam and Velayntham (1972) are given in Table 5.

TABLE 5. RECOMMENDATION FOR FERTILISATION OF BANANA

State	Rate	N	P_2O_5	K_2O
Tamil Nadu	kg/ha	110	35	330
Kerala	gm/plant	225	225	225
Karnataka	kg/ha	336	224	224
Maharashtra	kg/ha	350	—	175
Goa	gm/plant	400	200	400

Twyford and Walmsley (1973, 1974) reported the mineral composition of Robusta banana, its uptake and distribution pattern. It has been estimated that 10 tonnes of crop remove 20 kg N, 2·2 kg phosphoric acid and 50 kg of potash from an acre of banana plantation (Anon, 1976). For Champa, a commercial variety of West Bengal 224 gm N, 56 gm P and 112 gm K were recommended per clump per year (Anon. 1976). According to Pillai *et al.* (1977) the yields were highest with N and K at 190 and 301 gm plant/year respectively, in Nendran banana in Kerala. However, they suggested that optimum economic rate being about 133 and 260 gm plant/year respectively. Singh *et al.* (1977) observed that treatment with N, P and K at the rate of 150, 90 and 170 gm/plant, respectively gave the highest yield and improved the quality in banana variety Basrai dwarf. A detailed review of works done in African countries on the principles and practices of banana nutrition has been made by Martin-Prevel (1978). In Tamil Nadu, Pillai and Khader (1980) recommended application of N (100 kg), P (40 kg) and K (400 kg) per acre in 3 split doses for better yield in Robusta banana. From an investigation on the pattern of uptake and utilisation of nutrients Balakrishnan (1980) found that triploids in general, showed the highest N uptake, Robusta ranking first with 220·92 gm/plant, followed by tetraploids and diploids. The uptake pattern was slow at the initial growth phase and was exponential from the 15th leaf stage to flowering stage. Uptake of P was found to be positively associated with ploidy. It increased with increased ploidy level. The requirement of P was comparatively less than that of N. The trend of uptake was found increasing up to harvest in diploids and up to flowering in triploids (22·64 gm/plant in Champa AAB) and tetraploids, thus indicating the need for adequate supply of phosphorus in the early stage of growth.

Triploid Monthan (Kanchkela, ABB) showed the highest requirement of K (1071 gm/plant), while Robusta (AAA) required the lowest (611 gm/plant). In general, varieties of *M. balbisiana* derivatives had greater need for K than pure *M acuminata* varieties. A noteworthy feature was that the uptake pattern of K was continuous throughout the plant life in 7 out of 8 varieties studied. Increased production in banana variety Giant Governor by using complete fertiliser (N = 240, P = 45, K = 240 gm/plant/year) was also reported by Chattopadhyay (1981).

Recently, the International Group on Mineral Nutrition of Banana has brought out a bibliography listing 803 references on the mineral nutrition of banana.

Micronutrients

Role of micronutrients in banana production is yet to be thoroughly investigated. However, iron deficiency has been recorded in alkaline soils and is identified by interveinal chlorosis of young leaves and application of iron sulphate is beneficial. Zn deficiency is indicated by bunchy top crowns, narrow, pointed and chlorotic young leaves and application of $ZnSO_4$ corrects the deficiency. Srivastava (1964) from a study on micronutrient requirement of banana variety Basrai recommended foliar application of Cu, Zn, Mo, B and Mn for healthy growth. Beneficial effect of micronutrients (Mg, Fe, Mn, B, Zn, Cu, Mo) on the growth and the yield of banana was reported by Hernandes-Medina and Lugo-Lopez (1969).

Intercropping

At the earlier stages of growth, intercrops can be easily grown in banana plantation. Mixed cropping is also practised in some parts of India. In Kerala, vegetables like brinjal, colocasia, yam, dioscorea, chilli and lady's finger are grown as intercrop (Rao, 1974). Mixed cropping of banana, arecanut, coconut is a common practice along the coastal belts of Tamil Nadu. Paddy is also grown as mixed crop. Banana is grown as a shade plant for coffee, cocoa, rubber, orange and young mango trees in different parts of India (Singh, 1979). In West Bengal, vegetables like brinjal, radish, cauliflower, cabbage, spinach, chilli, cucurbitaceous vegetables, basella, etc., and papaya are grown (Anon., 1976). Intercropping gives additional income to the grower. In an experiment Devos and Wilson (1979) observed no significant decrease in yield of banana when intercropped with cocoyam, maize and casava.

Interculture

Weeding : In banana weed is a problem at the early stage of growth. Weed free environment is essential in banana field for conservation of moisture, proper utilisation of nutrients as well as for effective control of pests and diseases (Chambers, 1970). Spading is the usual method of controlling weeds and four spadings a year are found effective in most areas.

Application of chemicals has also proved effective in controlling the weeds in banana. Nine herbicides were tested by Leigh (1969) and the best result was obtained with Diuron applied at the rate of 3 lb (1·35 kg) and 6 lb (2·70 kg) /acre in conjunction with Diquat at (1·12 litre). Pre-emergence application of Chlorobromuron at the rate of 3 lb (1·35 kg) and 6 lb (2·70 kg)/acre and Chlorobromuron 0·5 lb (0·22 kg)/+Paraquat 0·25 lb (0·11 kg)/acre gave excellent weed

control in banana (Seeyave, 1970). Satisfactory weed control in Dwarf Cavendish banana with Diuron (2, 4 or 6 kg/ha) was reported by Dhuria and Leela (1971). According to Das and Misra (1979) Diuron at higher rates (4-6 kg/ha pre-emergence) was effective in controlling weeds. They obtained the highest yield (35·53 t/ha) with Simazine at 6 kg/ha. According to Ramdas *et al*, (1980) pre-emergence application of Diuron at 4 kg/ha controlled grasses and broad leaved weeds without affecting the yield and quality of banana.

Desuckering : Suckers are produced from the rhizome of banana. The number of suckers produced per clump varies depending on variety, soil fertility, environment, etc. Removal of unwanted suckers is one of the most critical operations in banana cultivation and is known as desuckering. It is done either by cutting off the sucker, or the heart may be destroyed without detaching the sucker from the parent plant. Tai (1962) tried several agents and concluded that kerosene was probably the safest and most reliable material. In South India, crowbar with a chisel-like end is used for damaging the sucker.

Satyanarayana *et al*, (1980) reported that removal of suckers with a portion of corm at an interval of 5-6 weeks hastened shooting and increased the yield by 12 per cent over control in the variety Karpura chakkrakeli.

In India, fruits are also harvested from ratoons. Therefore, setting the follower or followers is also very important. Not more than two suckers per clump should be retained at any time. Retention of suckers should be so regulated as to harvest fruits when the price is high. This will mainly depend on the experience of the grower.

Earthing up : Earthing up should be done during the rainy season to provide drainage, and to avoid waterlogging at the base. During summer and winter, the plants should be in furrows and on ridges during rainy season. There is a chance of the clump growing out of the soil unless they are kept in the furrows as banana throws sucker mainly from upper part of the corm.

Propping : Where wind is a problem, pseudostem requires to be propped up with bamboos, especially, at the time of bunch emergence.

Wrapping : Covering of the bunches protects the fruits from sun burn, hot wind and dust, and improves the colour of the fruits. Bagging of bunches is practised in New South Wales and Queensland (Berrill, 1956) and Israel (Comelli, 1960) and it has also been recommended in India (Gopalkrishnan and Deo, 1960).

Removal of dried and decayed leaves and plant parts : Dried, diseased and decayed leaves and plant parts should be removed to keep the plantation clean. The pseudostem should be removed after harvest. Clean and healthy plantation ensures less attack of pests and diseases.

Removal of male bud and floral remnants : The male bud is removed in some varieties. Removal of male bud is said to promote fruit development. The male

flower bud of some of the varieties is edible and thus fetch additional income to the growers. The most favourable time for removal of floral remnants is shortly after flowering (Daudin, 1953, 1955). In New South Wales, male bud is kept to readily recognise bunchy top disease.

Economic life of a plantation

The economic life of a plantation depends on several factors. Generally, dense planting and under-nutrition reduce the life of a plantation to a great extent. Normally, a plantation is retained for about 3-5 years. Results of experiments conducted in West Bengal showed that Champa plantation may be kept up to 15 years with proper cultural practices and fertilisation (Anon, 1976). The oldest banana plantation of 100 years was recorded in Madras by Cheema, Bhat and Naik (1954).

6.8 Growth and Development

Growth and development of banana has been studied by many workers. A review by Turner (1970) describes the overall growth of the plant, of individual organs and various processes, especially, those concerned in flower and fruit formation. Some of the important points covered in this review are briefly presented below.

In giant varieties, the parental dominance over the young sucker persists until the parent plant is harvested. However, in the Dwarf Cavendish varieties dominance is not long lasting. When the sucker is released from dominance new leaf blades broaden and presumably the plant becomes photosynthetically independent. The corm and pseudostem increase in size until the emergence of inflorescence. Increase in size of lamina does not continue after the leaf emerges fully.

Leaf-pseudostem-corm

Depending upon season of emergence, nutrition and stage of growth, leaf longevity varies from 55 to 165 days in the tropics. The time interval between emergence of successive leaves (phylacron) varies considerably. It is reduced by low temperature. It decreases with increasing plant age and is effected by mineral elements. An average time interval for tropical climate is 7 days. The total number of leaves produced varies depending upon several factors. Estimates by different workers (Oppenheimer, 1956 : 30 46 ; Champion, 1961 : 23-43 ; Summerville, 1944 : 35-40) vary due to climatic, nutritional and genetic differences. Lower leaf numbers are recorded in tropics than in subtropical areas. Each leaf is normally larger than its predecessor, but the last 2-3 leaves

which emerge prior to the bunch are smaller. The phyllotactic pattern changes gradually from $\frac{1}{3}$ to $\frac{2}{5}$ to $\frac{3}{7}$ to $\frac{4}{9}$.

In flowering of banana, age is the dominant factor to give the stimulus. Flowering cannot be induced by changing day length or by vernalisation. In estimating the occurrence of flowering in the field, two approaches have been adopted - (i) a fixed number of leaves is produced prior to bunch initiation and (ii) a fixed number of leaves remain in the pseudostem at bunch initiation. In Central America, differentiation of bunch in Gros Michel was found to occur after the production of 45 leaves, while for Dwarf Cavendish in Israel 23 was considered critical. Other data indicate that the number of leaves remaining within the pseudostem at bunch differentiation is relatively constant (10-12 leaves in Poyo ; 9-11 in Gros Michel) though in one case, eleven leaves were found in vegetative plants also. While the number of leaves produced prior to bunch differentiation varies with the variety and locality, the number of leaves remaining within the pseudostem seems remarkably constant over a range of varieties and climatic conditions.

There is also the leaf function hypothesis in estimating banana flowering. It involves computation of the product of leaf area, leaf longevity, and temperature and daylight hours received by each leaf When the product of these values (Ts) reach a certain figure the bunch is said to be initiated. According to this, the bunch initiation occurs at a Ts of $5{\cdot}6 \times 10^{11}$ whereas differentiation occurs at about $6{\cdot}3 \times 10^{11}$; but this concept has not been favoured as a generally applicable hypothesis. Ts has never been verified experimentally and it has not been tried in the tropics.

A third hypothesis points out that there is an interaction between corm and leaf. In the development of any one plant, a certain leaf area must be produced before initiation occurs, for in a population the vegetatively largest is not necessarily the first one to bunch. It is, therefore, considered that while function of the leaf system is important, the corm must have developed sufficiently to receive the flowering stimulus from the leaves.

A brief report of the work done on certain aspects of banana growth and development at the Tamil Nadu Agricultural University is given in the following paragraphs. The data relating to observations recorded on vegetative growth and bunch characters of eight clones representing the six genomes are consolidated and given in Tables 6 and 7 which are self-explanatory. Tzudir (1980) studied certain aspects of growth and development of Robusta banana and a summarised version of his observations is presented in Table 8. Some of his important findings are as follows :

The growth pattern of the plant suggested a double sigmoid curve, while the dry matter increase followed a normal sigmoid curve.

Throughout the period between the third month after planting and harvest, pseudostem contributed maximum to the fresh weight of the whole plant. Seven

TABLE 6. VEGETATIVE GROWTH CHARACTERS OF CERTAIN BANANA CLONES (Balakrishnan, 1980)

Clone		Pseudostem*		No. of suckers**	No. of ** leaves	No. of functional leaves (a)	Lamina** area (m^2) (b)	Leaf area duration (c)	Phylacron** (days) (d)
		Height (cm)	Girth (cm)						
Anaikomban	AA	177	49	9·70	32	14	11·8	3422	10·1
Kunnan	AB	175	45	7·26	33	15	9·5	4042	9·1
Robusta	AAA	186	61	5·63	34	17	15·3	4469	10·5
Wather	AAA	192	54	5·76	29	16	14·3	4688	10·8
Poovan	AAB	260	58	4·56	31	15	15·7	4868	10·6
Monthan	ABB	301	68	7·50	36	17	18·7	3133	8·7
Hybrid Sawai	ABBB	289	72	4·40	34	15	17·5	3151	10·3
Klue teparod	ABBB	234	73	2·93	33	16	13·6	1976	12·2

* Flowering stage
** Harvest stage
(a) Photosynthetically active leaf
(b) (Leaf length × breadth) 0·8
(c) Summation of area of each individual leaf × longevity in days
(d) Time interval in days for the appearance of successive leaves

months after planting, it accounted for more than half of the total fresh weight of the whole plant (51·27%) and was followed by corm and leaf contributing almost equally to the total fresh weight. After shooting, the contribution of the bunch to the total fresh weight became prominent, contributing about 32·17 percent of the total fresh weight at harvest and was very close to the fresh weight of the pseudostem (36·55%) at the same stage.

A total number of 32 leaves was produced by the variety studied. The total leaf area of the whole plant was largest at shooting (19·04 sq m). The mean leaf area of an individual leaf was largest at seven months after planting (1·37 sq m), i.e., a month before shooting.

TABLE 7. BUNCH AND FRUIT CHARACTERS OF CERTAIN BANANA CLONES (Balakrishnan, 1980)

Clone		Bunch weight (kg)	Hands /bunch	Fingers /bunch	Fruit weight (kg)	Peel /pulp ratio
Anaikomban	AA	6·65	5·5	68·13	86·66	1 : 1·44
Kunnan	AB	6·86	6·4	64·56	105·20	1 : 5·04
Robusta	AAA	20·62	7·8	110·56	171·33	1 : 2·57
Wather	AAA	12·66	4·9	59·06	191·56	1 : 3·60
Poovan	AAB	12·28	9·9	135·13	82·20	1 : 3·50
Monthan	ABB	10·83	5·2	55·30	186·46	1 : 2·00
Hybrid Sawai	ABBB	9·50	6·2	80·16	95·23	1 : 2·03
Kluc teparod	ABBB	7·80	6·6	72·80	89·13	1 : 4·00

TABLE 8. GROWTH AND DEVELOPMENT OF ROBUSTA BANANA (Tzudir, 1980)

Characters	Days after Planting			
	90	240 (shooting)	300	360 (harvest)
Pseudostem height (cm)	104·50	242·10	242·10	242·10
Pseudostem girth (cm)	23·10	71·70	71·70	70·50
Number of suckers	1·70	7·86	8·50	9·25
Single leaf area (m^2)	0·18	1·27	—	—
Total leaf area (m^2)	6·40	—	16·45	12·50
Number of total leaves	15·80	32·00	—	—
Number of functional leaves	10·20	—	12·60	9·60
Length of fruit (cm)	—	12·60	16·33	19·50
Girth of fruit (cm)	—	7·34	9·06	13·50
Fruit weight (g)	—	25·40	75·40	239·73

High values of NAR, RGR, CGR and LAR in the vegetative-transition stages were observed apparently due to a contribution of reserve materials in the corm, indicating the need for planting optimum-sized suckers to give a good start. Highest values of NAR, CGR and LAI at reproductive-shooting stages coincided with the stages when the plant produced highest leaf area and number. Upsurges in NAR, RGR and CGR values of whole plant and individual fruit at mid-late maturity stages support the hypothesis that current photosynthesis of the fruit peel in fruit bunch contributed significantly to the increase in dry matter.

Root

The pattern of root growth and development and the orientation and distribution of roots in three banana varieties, viz., Robusta (AAA), Nendran (AAB) and Monthan (Kanch Kela) (ABB) under different plant densities were studied by Mohan (1980) at Coimbatore. The rate of root growth varied from less than 1 mm to 25 mm per day. The last flush of root growth occurred about one month prior to shooting. Monthan recorded the highest rate of growth followed by Robusta and Nendran. About 70 per cent of total root dry matter was recorded on the surface zone (0 to 15 cm) and it decreased with increase in plant density. Large-sized roots (more than 4 mm) contributed to more than 85 per cent of the total dry weight. Among the varieties, Monthan recorded the highest horizontal and vertical root spread, largest root number and total root length followed by Robusta and Nendran. The zone of nutrient uptake in 2 months old plants was within 30 cm, while in 5 months old plants it was within 30 cm in closer spacing (1·85 m × 1·85 m and 1·55 m × 1·55 m) and within 60 cm in wider spacing (3·10 m × 3·10 m and 2·15 m × 2·15 m). The highest CEC was recorded at shooting and decreased sequentially in vegetative, early vegetative and harvesting stages. The large-sized roots from wider spacing at surface zone recorded the highest CEC, rate of nutrient translocation (^{32}P) and exudation, while the fine roots in closer spacing at lower soil depth recorded the lowest. Monthan harboured the highest rhizosphere microorganisms (bacteria, actinomycetes and fungi) followed by Robusta and Nendran. Microbial population was high at wider spacing, increased till shooting and declined thereafter.

Sucker production

Production of banana suckers in large numbers is currently receiving attention in the wake of great demand for elite planting material. Besides, rapid multiplication of suckers in successful hybrids will enable their quick spread in a short period.

Sucker production in banana is influenced by a complexity of factors. In a study by Balakrishnan (1980) the diploids ranked first in sucker production

followed by triploids and tetraploids in the order. Pure *acuminata* diploids and triploids produced larger number of suckers than the *balbisiana* derivatives. However, Monthan (ABB) was an exception in producing large number of suckers.

The stature of the plant was found to be unrelated to sucker production. The tetraploids which were large in stature were poor in sucker production.

In relating the girth of pseudostem to sucker production, it was found that the diploid Anaikomban (AA) and triploid Monthan (ABB), which had thicker pseudostems within their respective ploidy levels, produced more suckers.

The number of functional leaves appears to have a bearing on sucker production. The varieties Robusta, Wather and Monthan had higher number of functional leaves than in Poovan (Champa) and therefore, produced profuse suckers. The tetraploids had lesser functional leaves and they were poor in sucker production. The maintenance of higher photosynthetic area resulting in increased elaboration of metabolites might be responsible for increased sucker production.

Leaf area is one of the attributes to predict the yield of crop. It was also found that there was concomitant increase in the number of suckers with the increase in the leaf area of the diploids, triploids and tetraploids. Similarly, the leaf area duration is another contributing factor for sucker production. The varieties having increased leaf area duration produced more suckers.

The nutritional status of the mother plant has an overwhelming influence on sucker production. The findings of the study made by Balakrishnan (1980) revealed that among the varieties, greater uptake of nutrients by a variety of the same ploidy level resulted in more sucker production. For instance, Anaikomban (AA) among the diploids and Monthan (ABB) among the triploids showed higher uptake of nitrogen with resultant increase in the production of suckers.

In respect of the influence of corm size on sucker production, it was found that the tetraploid Kluc teparod which had the largest corm was poor in sucker production. However, the triploid Monthan (ABB) produced the largest number of suckers among the triploids. Therefore, corm size had no direct influence on sucker production. The diploids with a small corm produced the highest number of suckers.

Sucker production has been found to vary with the varieties since the trait is a characteristic of each varie conditioned by the level of ploidy.

The number of developed buds on a corm at planting had a strong influence on the number of suckers produced. It was also found that the number of swollen buds on the corm had a positive association with the number of suckers produced. The number of developed buds was high in the corm of the varieties Anaikomban (AA) and Monthan (ABB) which resulted in increased sucker production.

6.9 Flower Bud Initiation and Differentiation

In the evolution of cultivated bananas, hybridisation and polyploidy played dominant roles. But these two phenomena have probably not altered the basic developmental pattern of the inflorescence.

The whole developmental processes of the growing apex from vegetative shoot to inflorescence was studied by Chakrabarty (1977). He found redistribution of growth in different zones at various stages of development. In the vegetative phase, the flank meristem was the sole centre of growth activity where leaf initials were produced and leaf production was the chief activity of the growing point. Leaf initials were produced by quick cell division both anticlinally and periclinally, and primordial leaves were found cut off a little below the tip in a regular sequence. He believed that some regulatory metabolites must be elaborated by the plant in the zone of active growth for quick cell division and cell enlargement to switch over from vegetative to reproductive stage. Tzudir (1980) working with Robusta recorded a profound influence of hormones, particularly ethylene in triggering the vegetative bud to a floral one. Concomitant increases in the levels of starch, sucrose, protein N, nucleic acids, ascorbic acid and amino acids at transition stage were also observed by him.

Chakrabarty (1977) also reported that both height and girth of the apex at transition stage increased, indicating higher metabolic activity of the apex for laying down more cells. Production of leaf primordium ceased at this stage and bract primordium started to initiate on the wider apex in quick succession. The first distinguishing feature between vegetative and reproductive apex was the production of bract primordium with a thinner base, distinguishing from leaf primordium with a broader base. The important peculiarity of the reproductive apex was the initiation of hand primordium at the axil of bract on account of some regulatory stimuli. Another growth centre of the reproductive apex was the hand primordium itself, which produced biseriate rows of meristematic bulges which ultimately gave rise to two series of flowers, the future fingers of a hand.

The interesting feature of the inflorescence is the production of a series of different types of flowers—female, hermaphrodite and male in a same floral stalk. Summerville (1944) reported that all the flowers at the initial stage are potentially hermaphrodite, and the femaleness is positively correlated with the meristematic activity, operating during laying of the fruit and the fruit number, which is influenced by the climatic conditions that prevail during the period of development of the last three or four leaves, i.e., a month or so before shooting.

The flower differentiates in the sequence of sepals followed by stamens and then carpels. A good deal of floral development occurs before the stem elongates and throws out the inflorescence. Fruit growth in terms of length occurs rapidly, immediately prior to and during the process of emergence.

Among the growth features in the elongation of the floral axis, Chakrabarty (1977) observed the apex showing the microscopical elongation and remaining at a very low level even after differentiation of bracts and hand primordia. Interestingly, there was a sudden spurt in elongation of the floral axis a month before shooting. Tai as quoted by Simmonds (1966) working on Lacatan in Jamaica, had shown that the inflorescence might ascend from the base of the pseudostem to the top in one month, the average rate being 8 cm per day. It indicates that there are two types of stimuli acting in the process—one for the initiation of floral parts which is elaborated earlier and the other for elongation of the floral stalk. The elaboration of the second type of stimulus should have attained its optimum level to synchronise with the rapid rate of elongation of floral stalk. Therefore, the dual factor stimulus of flowering hypothesis of Chailakhyan (1961) was found to fit in very well in banana (Chakrabarty, 1977). According to the hypothesis, one gibberellin-like substance acts upon the growth and elongation of the main stem and the other, anthesin, acts as flowering hormone to produce flower. Ram *et al*, (1962) were also in favour of this 'dual factors hypothesis' of flowering in banana.

6.10 Fruit Growth and Development

Banana fruits show, broadly, two main courses of development (Simmonds, 1953). The edible bananas are vegetatively parthenocarpic, i.e., they develop a mass of edible pulp without pollination, while pollination is essential for fruit development in the wild-seeded bananas. Simmonds also observed that they may or may not be seed-fertile, but they are effectively seed-sterile, depending upon a complex cytological factors. Ho (1968) reported that the edible pulp (starchy parenchyma), which fills the fruit in parthenocarpic types and surrounds the seeds in seeded banana, mostly originates from the outer lining of the locule. The increase in bulk of the fruit was mainly due to cell enlargement.

The observations on the development and growth pattern of pollinated and unpollinated banana fruits revealed that the growth in volume of seeded bananas is sigmoid and that of the parthenocarpic fruits is not sigmoid. He also found that the growth rates are related to certain ovule behaviour and seed content of the fruit and ploidy. The edible clones from *M. acuminata* have predominantly concave growth curves while those from *balbisiana* have convex and the hybrids have intermediate growth curve (Simmonds, 1953). Nayar *et al*, (1958) reported that the volume curve of Poovan was slightly straight and there was early growth check, while in Monthan growth curve was convex with no early growth check.

Tzudir (1980) reported that fruit growth in terms of increase in girth, length and volume followed a double sigmoid pattern, but it was not clearly defined in

case of the increase in fruit length. Increase in both fresh and dry weight also suggested a double sigmoid curve.

The growth in weight of the Gros Michel banana was studied by Wardlaw *et al*, (1939). They found that the fruit weight increased approximately linearly up to 80–90 days; thereafter the growth accelerated and finally, at incipient ripeness attained roughly double the size. Lodh *et al*, (1975) reported that the fruit length, girth, whole weight, pulp and pulp-peel ratio of Dwarf Cavendish increased with age. Lassondiere and Manbert (1971) measured the growth of fruits of Poyo bananas. At an early stage, mean daily increase was 4 mm in length and 3 mm in diameter. This was followed by a slower rate of growth up to 82nd day. There was no further growth in length up to 108 days when it was harvested. The rate of increase in girth of banana fruit was linear within a range of 18–29°C (Ganry and Mayer, 1972).

In case of Robusta, the increase in the weight of fruits from 30 days after flowering till the harvest stage was linear. Rate of growth of peel was very slow after 75 days from flowering and pulp-peel ratio increased from 1·08 at 30 days after flowering to 2·30 at harvest stage (Samaddar, 1982). Balakrishnan (1980) found marked variation in fruit weight in different varieties (Table 7).

Effect of chemicals on fruit growth

Venkatarayappa *et al*, (1978) recorded increased fruit weight and volume after spraying potassium hydrogen phosphate on bunches or on whole plant. Deshmukh and Chakrawar (1980) reported that application of Ancymidol at 100 ppm, 2,4, 5-T at 100 ppm or Racuza at 100 ppm proved more effective than GA_3 or Ethrel in increasing the size of fingers and bunch weight. Spraying of GA_3 (10^{-4} M) on 35 or 55 days' old banana bunches three times on alternate days increased the weight and volume of fingers in both young and old bunches (Misra *et al*, 1981).

6.11 Pests and Diseases

Pests

The most common pests reported to cause heavy losses in banana are the following:

Banana stem borer: The larva of two species of insects *Cosmopolites sordidus* and *Odiporus longicollis* feeds and tunnels inside the corm. The corm becomes riddled with tunnels which rots into a blackened mass. Leaves turn yellow, wither and the whole plant dies.

Dutt and Maiti (1972) recommended Celphos treatment at the rate of 3 tablets/plant for successful control of egg, larva, pupa and adult population of the insect. After placing the tablet inside the pseudostem the slit should be plastered with mud. Clean cultivation is an important measure for its control.

Banana aphid : The insect, *Pentalonia nigronervosa* is particularly important as it is the vector of the virus causing bunchy top disease. The insect can be controlled by spraying Rogor, Malathion, Metasystox.

Fruit and leaf scarring beetle : The beetle *Colaspis hypochlora* feeds on young leaves and skin of young fruits. This insect sometimes lives in the heart of the pseudostem within the roll of the central leaf. Occurrence of this pest is usually maximum during the rainy season. Severe scarring of fruit skin leads to underdeveloped fruit which fetches less price in the market.

Clean cultivation, particulary, the removal of grass weeds from plantntions where the population of this pest is high can often reduce the population levels enough to avoid the use of insecticides. Unless the beetles are causing serious economic losses the use of insecticides should be avoided. Low volume spray of Aldrin 0·25% a.i., controls the insect (Feakin, 1972). Dusting with Malathion is also effective.

Nematode : Burrowing nematode (*Radopholus similis*) is widely distributed in banana growing regions of the world. Affected plants do not respond to fertilisers, irrigation or cultural practices. Before planting, suckers should be treated with Furudon granular insecticide. Phytosanitary measures are also effective. The nematicide may be spread and granules may be placed round the plants. They are carried down into the soil by rain or irrigation water.

Diseases

Banana is much more vulnerable to diseases than to the insect pests. The diseases often occur in epidemic proportions and bring about catastrophic losses. Among the diseases, the banana wilt ranks first. In addition to fungal diseases, the bunchy top virus has created a situation of a dismal future for the banana industry.

Panama disease or Banana wilt (*Fusarium oxysporum cubense*) : The first major disease which attacked banana was called Panama disease from the area where it first became serious. Stover (1962) has summarised the researches done on Panama disease, in a monograph.

Banana wilt is a soil borne fungal disease and gets entry in the plant body through roots. It is most serious in poorly drained soil. Sudden yellowing of lower leaves, including leaf blades and petioles, is observed. The leaves hang around the pseudostem and wither. In the pseudostem of the diseased plant, yellowish to reddish streaks are noted with intensification of colour towards the rhizome. Greater incidence of the disease has been noticed in poor soil with continuous cropping of banana. Warm soil temperature and bad drainage favour the spread of the disease and also light soils and high soil moisture.

Basrai is immune and Poovan or Champa is resistant, while Sonkel, Rashthali, Malbhog, Alpan, Mortaman, Kanthali, Sirumalai, Monthan, Virupakshi are

susceptible. Other resistant varieties include Cavendish group, Moongil, Peyladan, Raja Vazhai, Vamankeli.

The diseased plants should be uprooted and burnt. Highly infected soil should not be replanted with banana at least for 3/4 years. Use of disease free planting material and resistant variety are recommended. Other measures include use of quicklime near the base of the plant and soaking with water. However, once soil is generally infested, there is no economic method of reducing the pathogen population to a level where more than two or three crops of a susceptible variety can be obtained (Stover, 1962).

Bunchy top : Banana industry in India is seriously threatened by this disease. It is a virus disease and is transmitted to the plant by the aphid vector *Pentalonia nigronervosa.* The dwarf bananas are very susceptible to this disease.

The leaves are bunched together into a rosette at the top and their margins are wavy and slightly rolled upward. The presence of interrupted dark green streaks along the secondary veins of the lamina or the midrib or petiole is a characteristic symptom of bunchy top. The diseased plants remain stunted and do not produce bunch of any commercial value.

The diseased plants along with rhizomes should be destroyed as soon as they are detected. Planting materials should not be collected from places affected by this disease. The aphid should be controlled to check spread of the disease by spraying with an effective insecticide (Metasystox 0·1 to 0·5%, Dimecron, Parathion). Herbicide like 2,4-D may be applied on the stool after cutting down for effective killing of the plant.

Regular inspection, roguing of diseased plants, and planting virus free corms have reduced bunchy top disease in Australia (Magee, 1927 ; Eastwood, 1947 ; Colborne, 1953). Bunchy top still causes heavy loss and continues to spread in other areas (Mehta *et al*, 1964 ; Vakili, 1969 ; Graham and Navaratnam, 1970). Field trials with Dwarf Cavendish banana revealed that phytosanitary measures help in minimising the disease to a great extent (Sastry *et al*, 1980).

Leaf spot or sigatoka disease (*Mycosphaerella musicola*--sexual stage, *Cercospora musae*--asexual stage) : Sigatoka is the name of the valley where the disease first attracted attention. A monograph (Meredith, 1970) has reviewed information on leaf spot disease. It is a fungal disease.

The first symptom of infection is the presence of light yellowish spots on the leaves. A small number of these enlarge, become oval ; the colour also changes to dark brown. Still later, the centre of the spot dies, turning light grey, surrounded by a brown ring. In severe cases, the numerous spots coalesce, killing large parts of the leaf. Infection occurs through the stomata of the young leaves, the lower surface being much more important than the upper. In Jamica, significant infection occurs only on the first three leaves, while in Queensland (Simmonds, 1939) the fourth and fifth leaves are also infected. Leach (1946) found that the older leaves are probably resistant to infection as a result of the presence of antogonistic

epiphyllae and gummy materials resulting from evaporation of dew. The heart leaf and the first unfurled leaf are the major sites of infection by ascospores and conidia. The stage at which these leaves are infected and in some cases whether ascorpores or conidia are involved can frequently be determined by the pattern of streaks and spots. These patterns have been well described by Stahel (1937), Leach (1946), Stover and Fulton (1966) and Meredith, (1970). Bunch grade and individual fruit size are reduced due to reduction of leaf area available for photosynthesis. Fruits of the affected plant remain angular, under-sized, and ripen prematurely.

Three components of weather, usually, determine the production and movement of sigatoka inoculum : rainfall, dew and temperature. Conditions favouring mass infection are most common during the rainy season with temperature above 21°C. According to Stover (1965) conidium production is very sensitive to temperatures below 22°C. Some sporodochium and conidia are also produced in rainfree periods, provided dew is present. Other factors, which influence the rate of disease development and intensity of spotting, include amount of inoculum on the leaf, age and position of the leaf, plant growth, sun and shade effects on leaf, tissue, etc.

The major commercial varieties of banana -Gros Michel and Cavendish varieties are all highly susceptible to leaf spot disease. All triploid AAA dessert bananas of commerce are highly susceptible to sigatoka, while all ABB clones are resistant. Vakili (1968) made a detailed study of the resistance and susceptibility to sigatoka in the genus *Musa*.

Cultivation practices which increase humidity, i.e., close planting, heavy weed or grass cover and failure to remove suckers favour in spreading the disease. Improved drainage, proper weed control, removal of suckers and proper spacing for the variety grown are important factors in reducing humidity within the plantation. Application of fertilisers according to recommendations helps the plants to recover from an infection. Recently, low volume oil fungicide-water emulsion spray has become popular. Phytosanitation, removal and destruction of badly spotted leaves and spray of Dithane M-45, Calixin, Zineb, Maneb or Cuman are recommended, both as prophylactic and control measures.

Pseudostem heart rot (*Botryodiplodia*, *Gloeosporium*, *Fusarium* spp) : It is a minor fungal disease. The first indication of heart rot is the presence of heart leaves with part of the lamina missing or decayed. In severe cases, the inner leaves of the crown first turn yellow, then brown and finally die. In more severe cases all the leaves and the plant die. Champa variety is susceptible to the disease.

Plantation sanitation, good drainage and proper spacing reduce the incidence of this disease. To prevent spread of the disease, spraying of Captan or Dithane M-45 or Dithane Z-78 is effective.

Main stalk rot : A black soft rot begins at the proximal end of the main stalk of the bunch. Affected parts shrivel and dry up. Premature ripening of fruits

often occurs when stalk rot is severe. The rot starts generally from sun-scald and hence it can be avoided by covering the stalk by the last spathe leaf at the curvature. Spraying of Dithane M-45 or Dithane Z-78 controls the disease.

Fruit spotting fungi can cause heavy losses of pre-harvest fruits.

Pitting disease (*Pyricularia grisea*)—Round, sunken pits appear on the fruit as it approaches maturity or after harvest. The centre of the pit may split. Pits do not extend to the pulp.

A sanitation programme is an essential part of its control. All collapsed and drying leaf tissues including transition leaves and bracts should be removed at regular intervals, particularly, during the rainy season. Fruit protection consists of weekly sprays of Dithane M-45.

Brown spot (*Cercospora hayi*)—Brown spots occur on the rachis, and fingers. The spots are pale to dark brown with an irregular margin surrounded by a halo of water soaked tissue.

The measures used for controlling pitting disease are also suggested to control brown spot.

Diamond spot (*Cercospora hayi, Fusarium* spp)—The spot is black, sunken, diamond shaped lesion, very much confusing with pitting disease. Diamond spot is prevalent after prolonged rainy season. Control as above.

Cigar end tiprot (*Verticillium theobromae* and *Trachysphaera fructigena*)—A black necrosis spread from the perianth into the tip of immature fingers. The corrugated necrotic tissues become covered with fungus and resemble the greyish ash of a cigar end.

Until recently, the only control was the removal of the pistil and perianth by hand as soon as the fingers emerged. Beugnon *et al*. (1970) showed that placing a polythene bag over the stem before the hands emerged was effective.

Bacterial soft rot of rhizome and pseudostem (*Erwinia* spp) : This is a minor bacterial disease, but causing concern in West Bengal. It is characterised by a massive soft odorous rot of the centre or a portion of the rhizome. The rot progresses up the pseudostem destroying the growing point and causing internal decay often with vascular discolouration. Externally, the symptoms sometimes resemble those of fusarial wilt. Yellowing and wilting of the leaves are the characteristic symptoms. Soil drenching with bleaching powder is beneficial.

Bacterial wilt or Moko disease (*Pseudomonas solanacearum*)—External symptoms are confusing with those of fusarium wilt of mature plants. On young plant, one of the youngest three leaves becomes pale green or yellow and collapses near the junction of the lamina with the petiole. According to Buddenhagen (1961) vascular discolouration differs from that of fusarial wilt ; in fusarial wilt discoloured vascular strands in the pseudostem appear larger in diameter

and are usually concentrated more peripherally. The presence of yellow fingers in an otherwise green stem often indicates the presence of Moko disease. Fruit rot and fruit stalk vascular discolouration, wilted or blackened regrowth of suckers, blackened and dead male flower buds, are characteristic symptoms of disease.

The basis of Moko control is early detection of the diseased plant and its rapid destruction along with adjacent, apparently healthy plants that may have contacted the disease. Flower visiting insects are main agents for transmitting the disease and this is a good reason for following the practice of removing the bud from the male axis before the bunch matures. Herbicides, eg., 2, 4-D and 2, 4, 5-T, can be used to kill infected plants *in situ* and Dieldrin sprayed onto a chopped down mat will prevent insects transmitting the disease to the unaffected plants (Feakin, 1972).

Fungal diseases of post-harvest fruits: Among the post-harvest fungal diseases, crown rot, stem-end or neck rot, main stalk rot, anthracnose, etc., are important.

6.11 Harvesting and Yield

The fruit is harvested when the ridges on the surface of the skin change from angular to round, i.e., after the attainment of 3/4th full stage. The dwarf bananas are ready for harvest within 11 to 14 months after planting, while tall varieties take about 14 to 16 months to harvest. A bunch usually takes 90 to 120 days to mature after shooting, depending on climate and cultural practices. In India, the main banana season is from September to April. The fruiting age of a plant, however, varies according to the size of the sucker at planting.

The yield of banana depends on a number of factors such as variety, plant density, management practices, etc. Tall varieties usually yield 15-20 tonnes/ha. A high yield was reported by Oppenheimer (1956) for the Dwarf Cavendish banana in Bombay. From the same clone in the Canary Islands, 40 tonnes/ha per annum appeared to be an average crop (Holmes, 1933). Eighteen tonnes of fruit per hectare per annum for Gros Michel in Central America and West Africa was probably the average, anything above 30-40 tonnes was exceptionally good (Simmonds, 1946; Borel and Pelegring, 1951; Bulter, 1960). In Egypt, Azouz *et al*, (1971) reported an yield of 19·7 tonnes/feedan. An yield of 47·54 tonnes/ha with Robusta banana was obtained by Randhawa *et al*, (1972).

Irrigary *et al*, (1978) recorded the combined production of 73·5 tonnes/ha in plant and ratoon crop. A yield of about 54·0 tonnes/ha was recorded by Chattopadhaya *et al*, from a plant population of 2500/ha in var. Giant Governor.

6.12 Packaging and Transport

In places around Bombay, the bunches are wrapped with banana leaves, but in most places the fruit is handled unwrapped. The Champa variety of West Bengal is exported to different areas of Bihar and Uttar Pradesh and dry banana leaves are used for packing purpose. The banana is packed loose in railway wagons with banana leaves spread between each layer of bunches in India. The fruits transported in the South in river boats receive little better handling. The methods of transporting banana from the orchard to the market are trucks, carts, rickshaws, cycles and head loads. Grading is done according to size, number of fingers, ripening and maturity stages of the fruits. The damage due to handling, transport, etc., is about 5-6 per cent.

6.13 Storage and Ripening

Storage

Banana can be stored at a temperature slightly above 55°F (13 °C) and a relative humidity of 85 to 95 per cent for about three weeks, and is ripened in a week or two at 62-70 °F (16·5-21 °C). Banana fruit becomes blackened at lower temperatures and should not be placed in a refrigerator. Internally, the banana is carried either by rail or by road in unrefrigerated carriage. On the other hand, the produce for overseas trades is carried in refrigerated ships, the banana being kept in a cool air circulation at about 52-56 °F (11-13·5 °C). Premature ripening is probably the biggest single cause of loss during storage. Experiments indicate that premature ripening can be reduced, i.e., storage life can be prolonged by keeping the fruit in relatively high concentration of CO_2 and low concentration of O_2. Dipping of bananas at 200 ppm TBZ has been approved and recommended as a post-harvest treatment (Rippon *et al*, 1970). Raman *et al*. (1971) noted that after 4 weeks of storage at 14·5 C°$\pm$1 °C and 80-90% RH, 64 per cent fruits of Robusta were fully ripe and Dwarf Cavendish were overripe. A double coating of 12% wax emulsion prolonged the storage life of Dwarf Cavendish banana by 10-12 days at 58°F (14·5 °C) as reported by Sadasivam *et al*, (1971). From a storage study, Muthuswamy *et al*, (1971) found that Dwarf Cavendish bananas can be stored at 14·4°C with 80-90% RH for 25 days. Simple polythene bagging was adequate for extending storage life by about a week at warm ambient temperature (Scott, 1975), while longer storage could cause ripening of green bananas due to ethylene accumulation, but a vermiculite/cement block soaked in $KMnO_4$ solution removes the ethylene and naturally extends storage life. Sen and Choudhuri (1976) noted development of black spot in cold storage of Champa variety. According to Broughton (1979), the recommended storage conditions for two banana cultivars (Pisang Rastali and Pisang Embun) are 20 °C with continued

ethylene removal and low (5-10% v/v) CO_2 concentration with RH about 80 per cent. It was also observed that application of ethylene was the best method to hasten ripening without loss in fruit quality or flavour. A pre-storage dip in E-9267 emulsifiable mineral oil at 0·4% was found effective in reducing fruit decay and also prolonging storage life (Seshadri *et al*, 1980).

Ripening

Bananas are not usually allowed to ripen on the tree as it takes long time. Moreover, the fruit-peel splits, fruit ripens unevenly and fails to develop good colour and aroma : hence the marketable quality deteriorates. Therefore, banana needs to be ripened artificially. On arrival at the destination, the banana bunches are immediately sold to wholesale dealers who store the fruits in loose heaps in godowns and ripen them in lots as per the need of the retail dealers. In our tropical conditions fruits for local consumption are harvested and ripened by hanging the bunches in a shady place.

Smoke treatment is the commonest method to induce ripening in Maharashtra and Tamil Nadu. Smoking is done with straw, leaves and cowdung in a closed chamber with bunches arranged in a heap for 18-24 hours in summer and 48 hours in winter. After taking the bunches from the chamber they are placed in a well-ventilated room for development of colour. According to Ram *et al*, (1979) smoke treatment, causes ripening of the bunches within 3 days. Ripening is also done by keeping the bunches covered with gunny sacks. Ethylene at a concentration of 1 part per thousand also helps to initiate ripening of banana.

In commercial trade, ripening is initiated by using various chemical substances. Growth regulating chemicals, such as 2, 4-D, 2, 4, 5-T, IAA and ABA have been tried to hasten ripening. Aziz (1970) noted that 2, 4-D is the cheapest chemical for inducing artificial ripening and 1000 ppm of 2, 4-D for 30 seconds was optimum. A post-harvest dip of banana fruits in ABA and IAA solution also hastened ripening (Desai and Deshpande, 1978). Use of acetylene gas generated from CaC_2 for ripening banana started as early as 1932. Since then CaC_2 is used on a large scale in case of ripening green mature bananas. When Basrai Dwarf bananas were exposed to Ethrel at 1000-3000 ppm and CaC_2 (10-25 gm) in paper-lined basket, Khan *et al*, (1977) observed shortest ripening time with highest exposure rates of both the chemicals used. Works carried out at the Department of Horticulture, BCKV showed that different concentrations (200, 400, 600 and 800 ppm) of ethrel caused development of good colour, flavour and taste of fruits of Giant Governor variety at different stages of harvest.

6.14 Breeding and Varietal Improvement

Breeding of banana is a difficult exercise due to complexities resulting from perthenocarpy, sterility, polyploidy and vegetative propagation. As the

degree of sterility is particularly high in edible varieties, breeding of banana is complicated, difficult and time consuming. Nevertheless, the results of work done since 1922 in the West Indies proved to be, in the word of Menendez and Shepherd (1975) an encouraging milestone of success.

In the West Indies, the problem of Panama wilt necessitated taking up of breeding programmes. In India, breeding work was started in Tamil Nadu in 1949 with the objectives of improving the bunch grade, the stature of the plant, etc.

In Trinidad, the first artificially produced hybrid banana IC1 was a tetraploid and was highly resistant to Panama wilt. It was evolved by crossing Gros Michel (AAA) with a wild-seeded diploid *M. acuminata*. Its bunches lacked symmetry. Fruits were shorter and number of hands per bunch were less. Other hybrids IC2, S19, J 1877 and Bodles Altafort produced subsequently, were also similarly unacceptable.

In India, the hybrids that resulted from the preliminary work carried out with 15 triploid varieties and four other species of *Musa* including *balbisiana*, were found inferior. The programme was, therefore, reoriented to include some of the commercial edible diploids already in cultivation in the breeding programme. Anaikomban (AA) and Tongal (AB) were found fairly resistant. A synthetic diploid (AA) evolved by crossing Matti (AA) and Pisang Lilin (AA) has high fruit quality of the former and nematode resistance of the latter. This new diploid has great potential to serve as a male parent in the future breeding programme. A new triploid hybrid H-135 (AAB) evolved through multiple crossing involving *M. balbisiana* is becoming popular.

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7

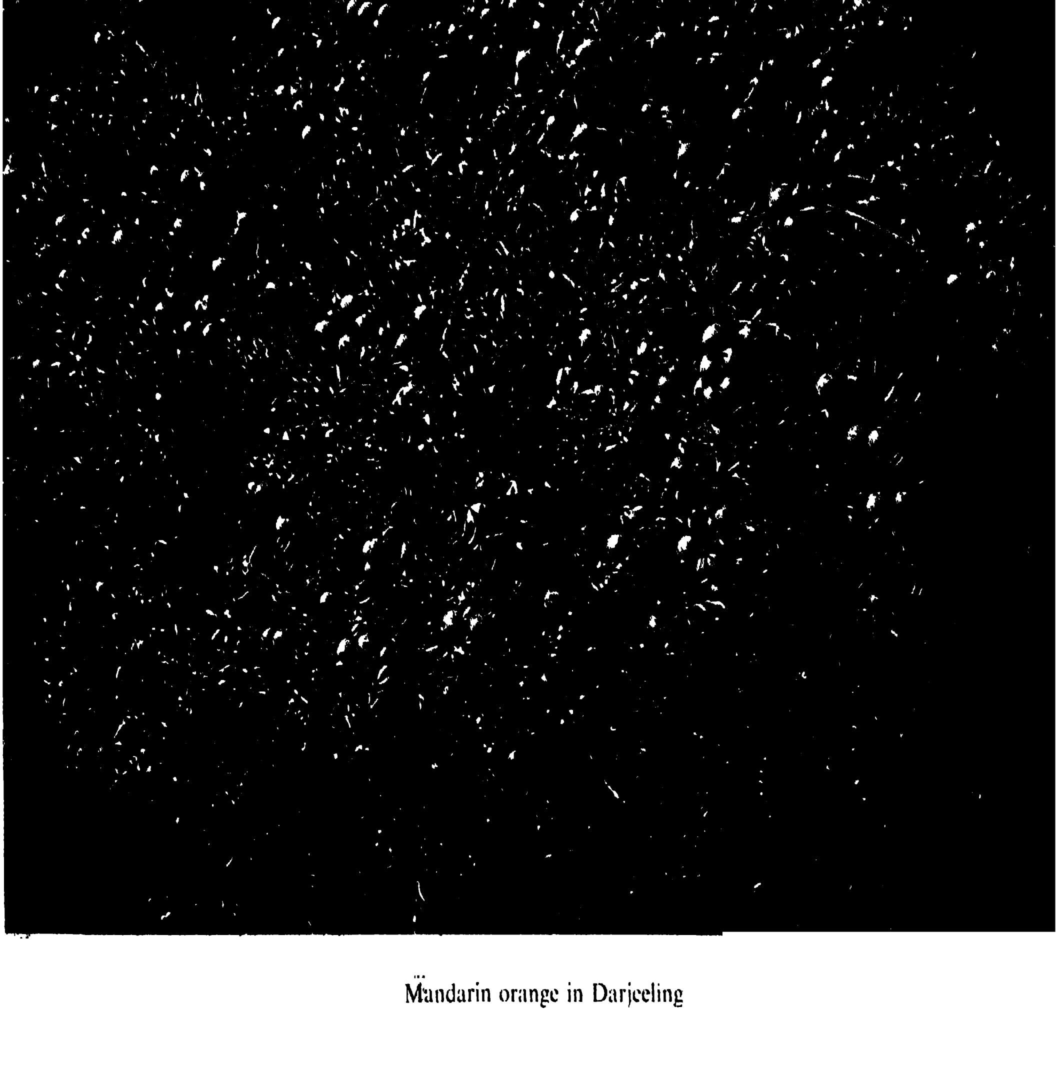
CITRUS

S. P. Ghosh

Citrus is one of the most important fruit crops of the world and although acreagewise it may stand third in position among all the subtropical fruits, valuewise it enjoys a better position. In India, it is the third most important fruit crop and rough estimates show that about 1·48 lakh hectare is covered under various species of citrus in the country with about 17 lakh tonnes of production (Directorate of Marketing and Inspection, Government of India, Nagpur). Citrus occupies about 9 per cent of the total land under various fruits of the country. The most important commercial citrus in India is the mandarin orange (Santras of Coorg, Assam and Nagpur) followed by the sweet oranges and the acid limes. The states like Assam, Meghalaya, Karnataka, Maharashtra, Andra Pradesh, Punjab, Rajasthan, are the major producing centres, while in certain other states like Haryana, Uttar Pradesh, Madhya Pradesh, West Bengal, Tamil Nadu, Gujarat, Bihar and Orissa the crop is grown to a limited extent.

7.1 Composition and Uses

Different species of citrus fruits have different chemical compositions. While in the sweet group, the principal constituents of the edible portions are sugars (glucose and sucrose) and acids (primarily citric acid and little of malic acid), the fruits of acid groups contain primarily the acids in the fruit juice. The rind of citrus fruits is rich in pectin and certain essential oils. The rind also contains certain glucosides (hesperidin in oranges, lemons and naringins in the grapefruit). Citrus fruits contain considerable amount of ascorbic acids, the vitamin C. The total soluble solids (TSS) in the fruit juice, in most of the sweet group of citrus, varies from 8-12 per cent, while the titrabie acidity usually ranges from 0·5 to 1·5 per cent. Usually, for oranges and mandarins a TSS-acid ratio of 8 : 1 and in grape fruit the ratio of 6 : 1 was considered to be optimum for marketable fruits. In the lemons and limes, titrable acidity of fruit juice usually ranges

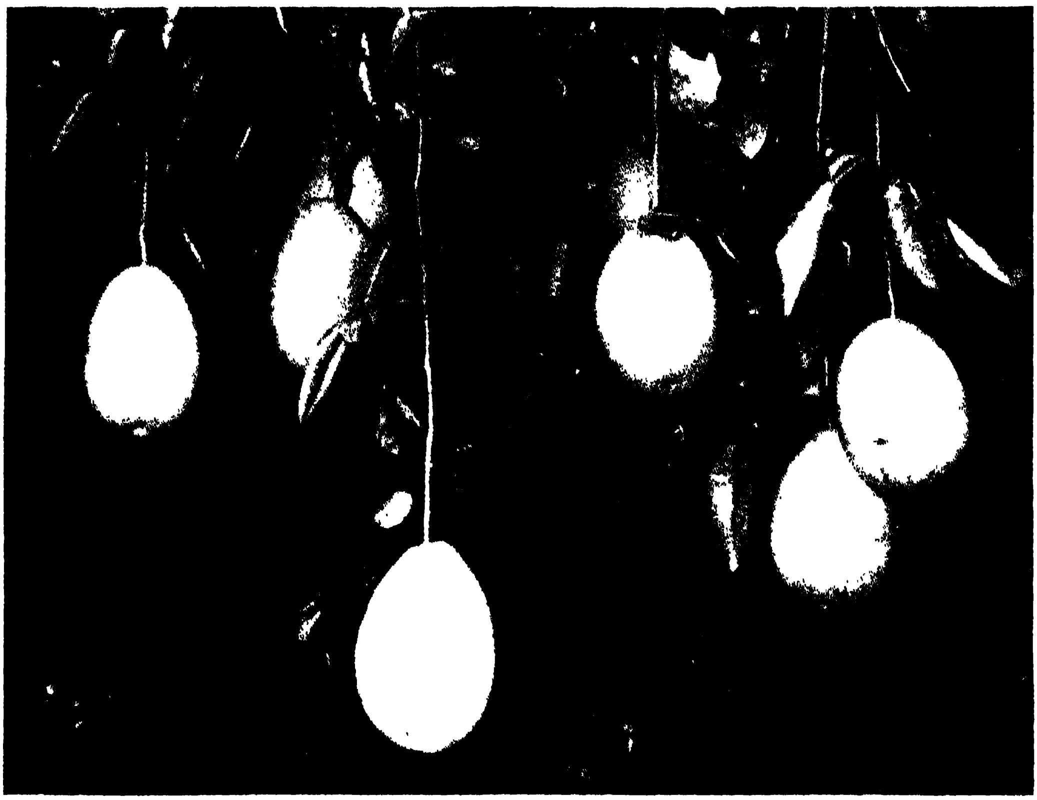


Mandarin orange in Darjeeling

Grape fruit

A branch with lemon

Sweet orange



Pumelo

from 5 to 6 per cent. The vitamin C (ascorbic acid) contents in the fruit juice of different citrus species have been recorded to be variable and 25 to 85 mg per 100 ml of juice could be recorded.

Besides world-wide demand of orange as fresh fruits, orange marmalade has long been an important product and is one of the main uses of the sour orange. Sweet oranges, grapefruits and other types are also used in this way, Orange, lemon, lime and grapefruit juices are bottled and canned in large scale. Lemon-barley water is prepared from the common lemon. The production of canned juice and pulp and particularly, of frozen concentrated juice has been increasing very rapidly throughout the world. The flowers, leaf and rind of citrus contain oils of good fragrance and has good commercial value. Lemon and orange oils are most important citrus oils used for flavouring purposes, followed by lime, grapefruit and tangerine oils. Other commercial products are citric acid and pectin, made primarily from cull and unmarketable fruits.

7.2 Origin and Distribution

It is believed that most of the species under the genus citrus are native to tropical and subtropical regions of South-East Asia, particularly, India, China and in the region between these two countries. The north-eastern region of India is considered as one of the natural homes of citrus—at least for a few species. Certain non-edible species like *Citrus indica*, *C. ichangensis*, *C. macroptera*, *Citrus latipes* are found to grow in wild and semi-wild state in the north-eastern region. Bhattacharya and Dutta (1956) considered them as indigenous to the area. Also different strains of citron (*C. medica*), sour pumelo (*C. megalaxycarpa*) rough lemon (*C. jambhiri*) and sour orange (*C. aurantium*) have been found to grow widely in semi-wild conditions in different north-eastern states of India (Verma and Ghosh, 1979). It is possible that since very early days, there might have been spread of different citrus species in the contiguous regions of their natural homes and there are possibilities of intercourses, particularly between China and India, so far as carrying of citrus germplasm from one country to the other is concerned. Through the process of natural hybridisation also, some new forms might have been originated. Although the introduction and spread of citrus fruits in Europe and the United States took place comparatively recently, some of them hold principal positions in the citrus industry of the world.

The major citrus producing countries of the world are USA, Spain, India, Italy, Japan, Argentina, Mexico, Brazil, Morocco, Algeria, Greece, South Africa, Australia, Israel, Egypt, Jamaica, etc. Sweet oranges, mandarins, grapefruits, lemons and limes are the principal citrus types that occupy the important commercial positions in the citrus industry. The United States is considered as

the largest producer of citrus fruits, covering about 35-40 per cent of the world's total production and the citrus fruits have spread on commercial scale to about 30 countries of the world.

7.3 Species and Varieties

There is a good deal of diversity in the views of classification of citrus, primarily, due to divergent concepts about the constitution of a valid species. The treatments of two world famous authorities on the subject—W. T. Swingle (USA) and T. Tanaka (Japan) are at two extremes. Swingle (1948) recognised only 16 species under the genus citrus whereas Tanaka (1954) described as many as 144 species. Swingle's treatment was not sufficiently comprehensive and he rejected most species considered to be of hybrid origin and which were not found to occur in nature in the wild form. He failed to cover many forms of horticultural importance and many species of Japanese, Chinese and Indian origins have been denied. Swingle divided the genus citrus into two subgenera, viz., Eucitrus having 10 species and Papeda having 6 species.

Tanaka's (1954) treatment, although considered as more comprehensive and detailed, contains excessive number of species, some of them being of doubtful validity. In the mandarin group alone, he described 35 species, resulting to much confusion and obviously to lesser practical utility. Tanaka divided the genus citrus into two subgenera, viz., Archicitrus having 98 species and Metacitrus with 46 species.

Considering the two extreme views expressed in the treatments of Swingle and Tanaka, attempts were made from time to time to formulate an intermediate or compromise treatment, which is more acceptable and is of greater utility. Contrary to Swingle's opinion, citrus forms of hybrid origin have been accepted as valid species, while species standing given to certain natural hybrids and certain cultigens by Tanaka are questionable and may be avoided. It is accepted that the characters employed for identifying a valid species of citrus should be free from the environmental influence, should be easy to discern, showing sufficient range of variation and should fall into clear-cut discontinuous categories. Certain characters which are principally employed in the identification and classification of citrus are :

(a) Leaf : margin (entire, serrate, crenate) and petiole (degree of wing development).

(b) Shoot : nature of branches (angular or otherwise), colouration of new growth.

(c) Flower : size (small to large), solitary or clustered, colour of petals (pigmented or not), coherence of stamens (stamens free or filaments cohering in bundles), number of carpels (locules).

(d) Fruit : form (presence and absence of apical papilla), shape, articulation, adherence of rind (loose or tight), nature of central axis (core open, solid), colour of pulp, seed size, colour of cotyledons.

Major citrus species of horticultural importance

In citrus industry, quite a good number of citrus species have been exploited commercially, some for direct fruit production, some as rootstocks in propagation, etc. In addition, quite a large number of intergeneric and interspecific hybrids have been developed. In the intergeneric hybridisation work, the related genera like *Poncirus* (trifoliate orange) and *Fortunella* (kumquat) have been extensively used in crossing programme with citrus and a few broad groups like citranges (trifoliate orange × sweet orange), citrumelos (trifoliate orange × grapefruit), citradias (trifoliate orange × sour orange), citrumuats (trifoliate orange × kumquat), limquats (kumquat × West Indian lime) have been developed. In the interspecific hybridisation programme, on the other hand, a few other groups like lemonimes (lemon × lime), tangors (mandarin × sweet orange), tangelos (mandarin × grapefruit) have been developed and some of them could be found to be of horticultural value. The major citrus species and hybrids of commercial importance are :

(i) The mandarins

(a) *Citrus reticulata* Blanco : A highly polyembryonic species of Chinese origin, having medium-sized upright trees, leaves lanceolate in shape with narrowly winged petiole. Fruits medium-sized, globose, sweet in taste, segments easily separable, core open at maturity, loose skinned, orange in colour, seeds pointed with light green cotyledons. The important varieties are Nagpur, Coorg, Khasi mandarin of India and Ponkan of China.

(b) *C. unshiu* : A polyembryonic species of Japanese origin, with small spreading trees, comparatively coldhardy. Midrib of the leaves is prominent and petiole narrowly winged but long. Fruits seedless with thin rind, colour orange at maturity. The famous Satsuma mandarins of Japan and Owari, Kara, Silver Hill, etc., are important varieties

(c) *C. deliciosa* Tenore : A Mediterranean origin, highly polyembryonic species trees, medium-sized, drooping growth habit. Fruits strongly compressed and yellow to light orange in colour with distinctive flavour. Fruits seedy and cotyledons light green in colour. The Willow-leaf mandarin, Kinnow and Wilking of USA and Blinda, an Algerian selection come under the species.

(d) Other species of mandarin groups namely *C. nobilis* (Kunembo of Japan, King of USA, tangors like Temple), *C. tangerina* hort. (Tanaka) (Dancy tangerine of Florida), etc., are of certain specific importance.

(ii) The oranges

(a) *C. sinensis* Osbeck - sweet orange : A highly polyembryonic species of Chinese origin. Trees medium-large with blunt pointed leaf apex and narrowly winged petiole. Fruits subglobose to oval in shape, orange coloured, tight skinned with solid central core. Fruit is sweet and flesh colour usually orange. Seeds are with whitish cotyledons. The species is of great economic importance for its excellent quality as well as its rootstock value to a limited extent. Quite a large number of varieties, viz., Mosambi, Malta Blood Red, Sathgudi of India, Valencia, Pineapple, Washington Navel (having a rudimentary secondary fruit embedded in the fruit apex) of the USA, Shamouti of Israel, Succari of Egypt, Dobla Fina of Spain, etc., are some of the commercially important varieties.

(b) *C. aurantium*—bitter or sour orange : Highly polyembryonic and cold-hardy species. Tree medium-sized, upright with dark green and distinctively scented leaves. Flowers large and very fragrant. Fruit medium-sized, orange-red skinned at maturity, central core semi-hollow and the primary oil glands in the fruit peel are beneath sunken areas. Flesh orange coloured, acid in taste with bitter after taste. Highly seedy and cotyledons white. The species was primarily used as one of the principal rootstock and flowers are used for perfumery purpose (oil of neroli). Since the species is intolerant to certain citrus viruses like tristeza, in more recent years this is being abandoned as rootstock.

(iii) Pumelos and grapefruits

(a) *C. grandis* L. (*C. maxima* Merrill)—pumelo or shaddock : A mono-embryonic species with large-sized fruits. Spreading, round-topped, almost thornless tree. Leaves large with broadly winged petiole. Lower surface of leaf is pubescent, particularly the main vein. Fruits large-sized, subglobose to pyriform in shape, with thick and spongy rind. Fruits sweet and moderately juicy. Seeds very large, coarsely veined and white within. Two types, viz., white fleshed and red or pink fleshed are available in India and varieties are named accordingly. Some of the named varieties are Kao Pan of Thailand and Buntan of Formosa.

(b) *C. paradisi* -grapefruit or pumelo : A polyembryonic species with round-topped spreading tree. Leaves large with winged petioles (less broadly winged as compared to pumelo). Unlike pumelo, leaves and new growth are non-pubescent. Fruit large but subglobose in shape. Rind surface and fruit flesh are yellowish in colour. Fruits highly juicy, sweet with bitter after taste. The central axis or core opens at full maturity. Seeds big but smooth surfaced and white inside. The varieties like Foster, Ruby, Marsh, Duncan (seedless), Thompson, etc., are of commercial importance.

(iv) Lemons, limes, citrons, karna khatta, etc.

(a) *C. limon* Burmann—lemon : A weakly polyembryonic species with medium-sized spreading trees. The new flushes are pigmented. Leaves not dark green and leaf margins are subserrated. Petioles medium-sized and narrowly winged. Flower buds pigmented and the pistil is densely dotted with oil glands. Fruits oval to elliptic with pointed nipple. Fruit surface smooth, light yellow and core solid. Seed cotyledons are white. The species is of great commercial importance and the varieties like Eureka and Lisbon (USA), Femminello and Monachello (Italy), Bernia (Spain) are important. The so-called bush lemon types (lemon-citron) like Kaghzi Kalan, Italian Round, Assam lemon, etc., of India are not true lemons. Lemon oil is one of the most important citrus oils used for flavouring purposes in soft drinks, baked goods, confectionary, etc., and is of good demand.

(b) *C. jambhiri* Lushington - rough lemon : A highly polyembryonic species of Indian origin. Tree medium to large and spreading in growth habit. Leaves are light green and serrations of leaf margin are not sharp. Fruits differ distinctly in shape and colour from lemons having roundish to subglobose shape with cavity or depression surrounding the apical papilla or nipple. Fruit skin usually rough and lemon-brown in colour. Flesh colour yellow, core open at maturity, cotyledons light green.

Rough lemon is one of the most important citrus rootstocks of the world. The species is adapted to wide range of soil conditions but better suited to light soils. It is fairly tolerant to many citrus virus diseases, including tristeza.

(c) *C. aurantifolia*—sour lime : A highly polyembryonic, distinctive species of great commercial importance. Tree is small, bushy with small but sharp spines. Leaves small with narrowly winged petioles. Flowers and fruits small. Fruits round to oval, greenish-yellow in colour and thin skinned. Core solid at maturity, flesh greenish in colour and juice highly acidic. Seeds small, smooth and cotyledons whitish. The Kagzi lime is the most important commercial variety of India. The variety is highly susceptible to tristeza virus and bacterial canker disease.

(d) *C. limettoides* Tanaka—sweet lime : A highly polyembryonic species of Indian origin. Trees medium-large and spreading in growth habit. The leaves medium-sized, petiole wing margined, leaf lamina light green and characteristically cupped (somewhat rolled). Flowers and fruits larger than acid lime and globose to ellipsoid in shape. Fruit surface smooth, greenish-yellow with thin rind. Flesh pale yellow to straw colour, core semi-hollow at maturity, juice sweet (flat) with little bitter after taste. Seeds medium in size with white cotyledons. There is no named variety, the 'Mitha-nimbu' or 'Sharbati' of West Bengal belongs to this species. It is commercially grown in certain countries like Egypt and has been employed as rootstock.

(e) *C. medica* L—citron : A monoembryonic species, considered as a native to India and susceptible to frost. Trees medium-large, spreading and irregular in growth habit. New growth pigmented, leaf margin serrated. Leaf size large and rumpled. Flowers large, petals pigmented on the lower surface and filaments generally hairy. Fruits large-sized, lemon-yellow in colour at maturity, oblong to oval in shape, in many cases style persist, semi-smooth to rough surfaced. Rind thick to very thick, hard and in some cases semi-sweet and aromatic. Pulp acidic but juice scanty. Seeds medium-sized and white inside. There is no named variety of citron in India but a few types of citron and lemon-citron hybrids are available in the country, particularly in the north-eastern region.

(f) *C. karna* Raffine—karna khatta : A moderately polyembryonic species of wide by used as rootstock in northern India. Tree medium to large, somewhat similar to that of rough lemon. Leaves large with serrulate margin and winged petiole. Flowers large and pigmented. Fruits medium, rind surface irregular and apical papilla well developed. Rind thick and moderately adhering. Fruit surface and pulp orange coloured. Fruits juicy and juice acidic in taste. Moderately seedy and cotyledons white. The Soh-Sarker of Assam belongs to the species.

(v) Intergeneric and interspecific hybrids

INTERGENERIC

(a) *Poncirus* × *Citrus*

(i) Citranges—a group having the parentage of trifoliate orange (*Poncirus trifoliata*) and sweet orange (*C. sinensis*). Some of the varieties are Troyer, Carrizo, Morton, etc. They are more vigorous than trifoliate orange and characterise with trifoliate leaves. Varieties like Troyer and Carrizo are widely used as rootstocks.

(ii) Citrumelos—trifoliate orange × grapefruit.

(iii) Citradias—trifoliate orange × sour orange.

(b) *Fortunella* × *Citrus*

(i) Limquats—kumquat × West Indian lime, illustrated by varieties like Lakeland, Eustris, etc.

(c) *Poncirus* × *Fortunella*—citrumuats.

INTERSPECIFIC

(a) Tangors--mandarin × sweet orange hybrids. The varieties like Temple, Clementine, Monreal, Umatilla are of some importance, mostly monoembryonic.

(b) Tangelos—mandarin × grapefruit, illustrated by varieties like Orlando, Sampson, Mineola, Seminole, etc.

(c) Lemonimes—lemon × lime, having a variety like Parrine.

(vi) Wild, semi-wild species and related genera

A few citrus species of wild, semi-wild and of less economic value are found to grow widely in the hilly areas of north-eastern region of India. Bhattacharya and Dutta (1957) described 17 different species and 52 varieties of citrus from the erstwhile Assam State alone. The north-eastern hill region is considered as one of the sites of origin of citrus and the species available in the region are :

(a) *Citrus indica* Tanaka - Indian wild orange : The species has been found to occur in nature in certain parts of Assam, Nagaland and Meghalaya. Plant bushy, medium-sized and grows well in marshy areas under forest shades. Fruits inedible, small-sized with slimy juice of acidic taste and unpleasant aroma. Seeds are very big and covers the major portion of the fruit.

(b) *C. latipes* Tanaka -Khasi papeda : A species found to occur under high altitude conditions (up to 1800 m above mean sea level) and trees are of vigorous growth habit. Leaf petiole winged and broad. Fruits medium-sized, subglobose, moderately juicy and acidic. A cold tolerant species.

(c) *C. macroptera* Monti—Melanesian papeda : A widely distributed species, trees vigorous. Fruits used by local tribals for medicinal purpose and in cooking. Leaf large with petiolar wing as wide and long as the lamina. Fruits medium-sized, subglobose, very juicy and juice highly acidic in taste. Two forms, namely, Sat Kara and Tith Kara, are available.

(d) *C. ichangensis* Swingle—Ichang papeda : Medium-sized tree with long lanceolate leaves and small fruits (4-6 cm diameter). Petiolar wing well developed, fruits inedible. A cold-hardy species.

(e) *C. assamensis* Dutta and Bhatta—Adajamir (*C. pennivesiculata* var. assamensis) : A distinctive species having crushed leaf aroma similar to ginger or eucalyptus smell. Medium-sized trees with thick glossy leaves. Fruits medium-sized, almost spherical and smooth surfaced. The fruit is of limited home use with acidic juice. The species was decribed as a new indigenous species from Assam by Bhattacharya and Dutta (1956) but it has been found to be the same as *C. pennivesiculata* (Tanaka), the Gajanimma of India.

(vii) Related genera

(a) *Poncirus*—trifoliate orange : A distinctive genus with single species *P. trifoliata* Raff. Plants deciduous with trifoliate leaves. Plants highly thorny and fruits inedible. Seeds polyembryonic and the species is principally used as rootstock for citrus.

(b) *Fortunella*—kumquat : A genus having a few species, out of which *F. margarita* and *F. japonica* are important. Small shruby trees with very small oval or round shaped orange coloured fruits. Seeds are polyembryonic. The fruits are used for candying and the plants for ornamental purpose.

7.4 Soil and Climate

Soil

Citrus can grow well in a wide range of soils, but unsuitability of the soil could also lead to failure of the crop. Soil properties like soil reaction, soil fertility, drainage, free lime and salt concentrations, etc., are some of the important factors that determine the success of citrus. It thrives well in deep, loose, well aerated soils devoid of any hard pan layers of calcium carbonate in the rooting zones. Ideal pH for citrus is considered to be between 5·5 to 7·5 but evidences show that with suitable management it can be grown with success in highly acidic (pH 4·5) soils and those containing free lime (pH 8·5). It is also highly sensitive to over-moist soil conditions within its root-zone and excellent growth of citrus had been observed in areas where water table is considered to be detrimental to citrus orchard health ; while defective drainage causes nutritional imbalance. Presence of *kankar* pan (calcium carbonate concentrations) within the feeding root-zone adversely affects the citrus health mainly by affecting permeability and aeration of such soils. Citrus trees are susceptible to salt injury and they cannot thrive well in saline-alkaline soil. Lime induces chlorosis and presence of excessive free lime renders phosphorus, iron, manganese and zinc less available.

In India, while the major mandarin orange growing belt of north-eastern hills comes under acidic soils of sandy to clay loam nature, the other very famous mandarin growing belt of Nagpur region comes under non-acidic and heavy black soils. The citrus soils of Punjab is light with a pH range of 6·4 to 9·0. It appears that loamy soil with comparatively heavier subsoil or even heavy soil with good drainage arrangements can be ideal for citrus.

Climate

Citrus belongs to the tender evergreen subtropical group and thrives well in frost-free subtropical to semi-tropical climate. However, occasional light frost can be tolerated by most of the citrus species. Being evergreen, citrus has no specific requirement for winter chilling, but cessation of growth activity during winter months helps in flower bud induction, resulting to spring flowering. Different citrus species exhibit a range of tolerance to temperature fluctuations, and the total heat during the growing season is extremely important for normal growth and productivity of various citrus species and varieties. The climatic

factors like temperature, moisture (rainfall and atmospheric humidity), wind and light intensity are of principal importance for citrus, of which temperature plays a key role. Usually, a low temperature ot 20 - 24°F(- 6·66 to - 4·44°C) is considered to be injurious to young trees, while mature old trees are killed at a temperature of about 12 to 16°F (- 11·11 to - 8·88°C). While the kumquats mandarins, *C. latipes*, *C. ichangensis* cantolerate low temperature, most of the citrons limons and limes are least resistant to cold injury. Grapefruits are most resistant to high temperature and can thrive well in even up to 120°F (48·83°C), citrons and lemons starts showing injury at 95 to 100°F (35 to 37·77°C). Hot winds and excessive heat during flowering and fruit set period are highly detrimental for good bearing and causes fruit drop and fruit sun-burn. Atmospheric humidity has bearing mainly on the physical characters of fruit whereas temperature imparts effects on fruit quality. Low humidity usually favours better colour development of fruits, while in more humid conditions the fruits are more juicy with thin rind. Citrus is usually considered as a light loving plant and the trees are sensitive to shading. Trees exposed to high light intensity usually exhibit paler foliage colour, while those under shade develop deep green foliage Trees under shade are usually poor fruit yielder but partial shading often results in higher fruit quality. Under higher mean annual temperature condition citrus fruits mature early, fruit size is bigger and the acidity development in the fruit juice remains lower. Fluctuations between day and night temperature intensifies colour development and accentuates sugar accumulation and acid formation. Different climatic factors influence both the vegetative growth of citrus plants as well as the productivity and physico-chemical characteristics of the fruits. The period from flowering to ripening also varies considerably on the basis of climatic environment of different locations. To site an example, the Khasi mandarin orange, when grown at lower altitudes of north-eastern region, the fruits mature by November-December but when grown in cooler higher altitude, they are harvested by February-March.

7.5 Area and Production

The exact up-to-date figures on area and production of citrus in India is not known and there lies considerable variations in the figures available in the literature. The estimated area and production figures of various citrus fruits with statewise break up are given in Table 1.

It is apparent from the Table that the mandarins (Santras) occupy the largest area, followed by sweet oranges and limes and lemons. The major mandarin growing areas are Coorg of Karnataka State ; Nagpur belt of Maharashtra ; Darjeeling district of West Bengal ; east and west districts of Sikkim ; Kamrup, Dibrugarh and Lakhimpur districts of Assam ; Khasi, Jaintia and Garo Hills of

TABLE 1. AREA AND PRODUCTION OF CITRUS IN INDIA

State/Region	Area (000 ha)	Production (000 tonnes)
1. *Mandarins*		
N.E.Region	12·3	132·7
Karnataka	18·0	252·0
Maharashtra	14·6	146·0
Punjab	11·6	28·9
Orissa	1·3	11·9
Kerala	2·0	24·2
Others	11·3	106·2
2. *Sweet oranges*		
Andhra Pradesh	20·8	249·5
Punjab	9·6	119·9
Maharashtra	8·1	105·3
Others	3·7	36·1
3. *Limes and Lemons*		
Andhra Pradesh	8·4	126·2
Maharashtra	2·9	37·7
Others	22·9	205·8

Source—Directorate of Marketing and Inspection, Government of India, Nagpur.

Meghalaya; Jampui Hills of Tripura; Tamenlong, Tipaimukh and Jiribam of Manipur; Mokokchung and Tuensang districts of Nagaland and certain parts of Mizoram and Arunachal Pradesh. The Kinnow mandarin has occupied considerable area in Punjab and in the foot hills of Himachal Pradesh. A strain commonly known as Desi Santra is also grown to a certain extent in this area. In the Coorg and Wynad tracts of Karnataka, the variety is known as Coorg orange, in the Nagpur belt it is known as Nagpuri Santra, in Darjeeling it is called as Darjeeling orange; and in Sikkim the variety in vogue is known as Sikkim orange. In Assam, the mandarin variety grown is known as Sumthira, while in Meghalaya it is known as Khasi mandarin or Soh Niamtra. From certain recent reports it is estimated that while mandarin orange occupies about 1250 hectares in West Bengal with the production of about 6250 tonnes of fruits, in Sikkim the area covered under the crop is about 800 hectares concentrated on both sides of Tista and Rangit rivers at an elevation between 300 to 1500 metres. The

estimated area and production of mandarin orange in other north-eastern region states/union territories are :

TABLE 2. AREA AND PRODUCTION OF ORANGES IN NORTH-EASTERN REGION

State/Union Territory	Year	Area (000 ha)	Production (000 tonnes)
Arunachal Pradesh	1973-74	0·2	0·2
Assam	1973 74	2·0	17·0
Manipur	1975-76	4·2	28·7
Meghalaya	1975-76	4·8	31·0
Mizoram	1975-76	0·4	1·7
Nagaland	1975 76	0·4	1·2
Tripura	1975-76	1·2	0·7

In the sweet oranges, the most important commercial varieties grown in the country are Mosambi or Musambi, Sathgudi and Blood Red Malta. Mosambi is most popular in the western India, while the Sathgudi is grown extensively in the South India. The Malta Blood Red grows well in the Punjab, Haryana and Rajasthan. The acid group members like limes and lemons are being grown in almost all the states under subtropical climate but the Kagzi lime, an acid lime variety, is a major commercial crop in the southern India, including Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu.

7.6 Propagation

Various types of citrus of commercial importance are propagated differently. While budding is almost universally practised in case of sweet oranges, grapefruits, etc., seedlings are being used for limes and mandarin oranges to a certain extent in north-eastern hills region and Coorg of India. In case of lemons and sweet lime, air-layering and even cutting are being employed for raising plants. Since seeds of most of the citrus species and varieties are polyembryonic, the nucellar seedlings obtained through seed propagation carry the true characters of the mother plants, thus enabling to retain the clonal characters as in vegetative propagation. The phenomenon of polyembryony also helps in raising uniform rootstock seedlings.

Rootstock

For grafting or budding, proper selection of rootstock is of profound importance. The availability of large number of graft compatible species and

varieties has made the choice of proper rootstock selection broader as well as complex. Rootstocks are known to impart marked effects on the vigour, precocity, productivity, physico-chemical characteristics of fruits, longevity of trees, disease resistance, adaptability to soil-climatic conditions, etc. Due to the presence of certain citrus viruses, infection of which may completely destroy the stock-scion compatibility relations, it has become highly essential to change the approach in citrus propagation. Bud-wood certification programme through identification of disease-free mother (donor) trees for scion wood and maintenance of nursery hygiene have become very important in the process of raising of propagating materials for citrus. Since proper stock-scion compatibility is not a fixed relationship for all locations and conditions, continuous rootstock trials are essential for a given set of growing conditions.

Some of the commonly used rootstocks are sour orange, rough lemon, trifoliate orange, citranges, karna khatta, Rangpur lime, mandarins, etc., brief characteristics of which are as below :

Sour orange (*C. aurantium*) : Sour orange has been extensively used in the past for propagating sweet orange, mandarin orange, grapefruit and lemon. It is hardy to cold, adapted to heavy soils, resistant to many soil-borne diseases, imparts semi-dwarfing effects on the scion and improves the fruit quality in general. Since the species is susceptible to tristeza virus it is being abandoned now-a-days.

Rough lemon (*C. jambhiri*) : A very important vigorous rootstock, well adapted to wide range of soils but prefers well-drained light soils. It is cold tender, fairly resistant to soil-borne diseases like *Phytophthora* root rot and tolerant to tristeza virus. Seedling growth vigorous in the nursery, but trees relatively short-lived, with early high yield followed by reduction in yield. Fruit quality on rough lemon rootstock is usually inferior.

Trifoliate orange (*P. trifoliata*) : A coldhardy, dwarfing rootstock having high degree of resistance to soil-borne diseases and the nematodes. It is tolerant to tristeza virus but highly susceptible to exocortis virus and unsuitable to saline and calcium rich soil. Adapts well to heavy soils and succeeds in soils which are too moist for other stocks. Trifoliate orange, when used as rootstock usually improves the fruit quality. Nursery growth is slow and budding is comparatively difficult.

Citranges (*C. sinensis* × *P. trifoliata*) : Some of the citrange varieties like Troyer and Carrizo have become important rootstocks in the recent years. They have wide range of soil adaptability, markedly resistant to soil-borne diseases and nematodes and tolerant to tristeza virus. This is a coldhardy, semi-dwarfing rootstock and improves fruit quality slightly. It is highly susceptible to exocortis virus and the Troyer citrange is apparently incompatible with lemon var. Eureka.

Karna khatta (*C. karna*) : Vigorous rootstock with wide range of soil adaptation. A rootstock of considerable importance in the North India but its

actual degree of resistance to soilborne and other diseases are not definitely known. It is not tolerant to tristeza virus and reported to be incompatible with sweet orange var. Blood Red Malta. Nursery growth of seedlings is excellent and budding success is good.

Rangpur lime (*C. limonia*) : A vigorous hardy rootstock with good adaptability to wide range of soil, particularly for heavy soil. It is tolerant to tristeza virus and certain soil-borne diseases. It has been found to be successful for mandarin orange in Coorg region, where good productivity has been recorded. It is susceptible to exocortis virus and burrowing nematodes.

Mandarin (*C. reticulata*) : Some of the mandarins, like Cleopatra, are coldhardy, moderately vigorous rootstocks, having wide range of soil adaptability and resistance to soil-borne diseases. Tolerant to tristeza virus, they are not resistant to nematodes. The rootstocks do not improve fruit quality.

Sweet orange (*C. sinensis*) : A moderately coldhardy rootstock of wide range of soil adaptation. It produces high yields of good quality fruit, tolerant to tristeza but susceptible to greening (mycoplasma) and soil-borne diseases. It produces long-lived trees but difficult to handle in the nursery.

Citrus taiwanica : It is a new rootstock under test in the recent years. Originating in Taiwan, it closely resembles sour orange in its field performance but, unlike sour orange, is tolerant to tristeza virus. It is also reported to be resistant to gummosis and moderately salt tolerant. It may not be a suitable rootstock for lemons.

C. macrophylla : It is said to be native to the Philippines and appears to be a good rootstock for lemon. It is highly tolerant to boron, soluble salts and lime. Its effect on long term production is, however, not known.

Considerable information on rootstock-scion relationship among different citrus species and varieties are available. Incompatibility was reported in Mosambi on trifoliate orange, *C. maxima* and also in Kagzi lime on *C. karna* or trifoliate orange (Singh, 1961). The trifolate orange was found to be most dwrafing rootstock for grapefruit, Washingtion orange and Valencia (Tukey, 1964). The most promising rootstocks for close density planting of nucellar Marsh grapefruit and Valencia were Rubidoux trifoliate orange, Rusk citrange, sweet orange × Rubidoux and Rangpur × Troyer citrange (Castle, 1980). Singh *et al*. (1980) found greater tree volume of sweet orange var. Pineapple, Jaffa, Mosambi and Valencia Late on jatti khatti and karna khatta than on Troyer and Rangpur lime. In case of Marsh nucellar grapefruit, trifoliate orange rootstock excelled over rough lemon and Cleopatra mandarin in terms of yield and fruit quality (Foguet *et al*. 1972). The TSS of Ellendale tangor was the highest on trifoliate (Devington and Duncan, 1978). Orange and grapefruit on Rangpur showed high productivity, better quality and good survival (Cohen, 1970). The best rootstock for Kinnow mandarin in the arid region of Punjab has been found to be jatti khatti followed by karana khatta

(Chohan, 1978). For Nagpur mandarin, Florida rough lemon was found to be superior to karna khatta, while trifoliate was incompatible (Singh and Singh, 1972-74). In Valencia orange, the highest yield was recorded on Troyer (Cox, 1974) and Mortan citrange (Wutscher and Shull, 1973). Vuillaume *et al*, (1981) found no rootstock to be universally good for all scion species. Thus, Clementine did best on *C. taiwanica*, Tahiti lime on *P. trifoliata*, Orlando tangelo on Cleopatra mandarin and Pineapple orange on Carrizo citrange. Fruits on *P. trifoliata* showed good organoleptic qualities but yields of orange, tangelo and Clementine on this rootstock were poor. The habit of growth of the scion and intake of mineral elements from the soil also depend much on the rootstock used. A good rootstock for citrus should ensure an economic orchard life of about 30-50 years along with its tolerance or resistance to soil and virus diseases. In addition to it, it must be polyembryonic, easily propagable with adequate and cheap sources of seeds. The reactions of major citrus rootstocks to important viruses, soil-borne diseases, nematodes, etc., have been worked out by various workers (Bitters, 1960 ; Ford and Fedar, 1969 ; Klotz *et al*, 1965 ; Capoor and Rao, 1967). On the basis of their resistance against tristeza, psorosis, exocortis, *Phytophthora* and greening, *C. jambhiri*, *C. limon* and Cleopatra mandarin were found suitable as rootstock for sweet orange, (Chowdhary *et al*, 1981). Chadha (1970) summarised the chief characteristics of major citrus rootstocks, so far as their susceptibility and resistance to common citrus diseases, nematode and salts, are concerned (Table 3).

TABLE 3. RESPONSE OF DIFFERENT ROOTSTOCKS TO DISEASES, NEMATODES AND SALTS

(T – Tolerant S – Susceptible)

Rootstock variety	Comparative tolerance to						
	Tris-teza	Xylo-psorosis	Exo-cortis	Gum-mosis	Citrus nema-tode	Burr-owing nema-tode	Salts
Rough lemon	T	T	T	S	S	S	Moderate
Trifoliate orange	T	T	S	T	T	S	Poor
Sweet orange	T	T	T	S	S	S	Moderate
Sour orange	S	T	T	T	S	S	Moderate
Rangpur lime	T	S	S	T	S	S	Moderate
Sweet lime	S	S	–	S	S	S	Moderate to poor
Cleopatra mandarin	T	T	T	T	S	S	Good to poor
Grapefruit	S	T	T	S	S	S	Moderate
Troyer citrange	T	T	S	T		S	—

Based on the available information on the rootstock trials and the general practices followed in different parts of India, it may be said that in Punjab and Rajasthan jatti khatti (*C. jambhiri*) continue to be the major rootstock for sweet orange, particularly, the varieties Malta Blood Red and Valencia Late. In Uttar Pradesh, karna khatta (*C. karna*) has been found to be promising for sweet orange var. Mosambi and Srinagar mandarin. In Andhra Pradesh and Maharashtra, Rangpur lime showed the best performance for sweet orange vars. Sathgudi and Mosambi. Rangpur lime also performed well with Nagpur mandarin in certain parts of Maharashtra. For high rainfall areas of Coorg and certain other South Indian States the rootstocks like rough lemon, Rangpur lime, Kodakithuli (*C. reshni* Lush), Cleopatra mandarin, trifoliate orange, citranges vars. Carrizo and Troyer have been found to be promising for Coorg mandarin. Multi-locational trials laid in certain parts of South India with Coorg mandarin revealed promising performances of Kodakithuli, Rangpur lime and citranges in South Coorg and Rangpur lime and Cleopatra mandarin in North Coorg of Karnataka ; Cleopatra mandarin, Rangpur lime, rough lemon and Troyer citrange in Wynad area of Kerala and Cleopatra mandarin and Rangpur lime in Salem and Kodakithuli in Pannaikadu of Tamil Nadu. Preliminary information from certain recently laid out trials indicate that rough lemon, Rangpur lime and Cleopatra mandarin may be promising rootstocks for Kinnow mandarin under Bangalore conditions in Karnataka, while Troyer citrange and Cleopatra mandarin showed promising performances with different grapefruit varieties in Hissar, Haryana. In north-eastern region, rootstocks like rough lemon and *C. volkamariana* showed good vegetative growth of Khasi mandarin in the early years.

Since most of the citrus species are polyembryonic, they produce both gametic and nucellar seedlings. The gametic seedlings are highly variable and possess low vigour, while the nucellar seedlings provide uniform materials with comparatively more vigour. It is now established that most of the known citrus viruses are eliminated in the process of nucellar embryony and the nucellar seedlings are initially virus free. This phenomenon is of great horticultural importance, as it provides an opportuntiy of escaping viruses in the nursery stock. When the tedious process of bud wood certification for virus free scion wood cannot be followed, it may be advisable even to use the nucellar seedlings of certain commercial citrus types for direct orchard planting. In fact, the old mandarin orange orchards of entire north-eastern region, including Sikkim and North Bengal and of Coorg are seedling origin. Similarly, most of the sour lime plantations have been raised through seedlings only. However, the seedling planting have got some disadvantages like late bearing, low yield and susceptibility to soil-borne diseases.

Budding

Selection of bud : Along with standardisation of rootstocks, proper selection of bud wood and use of certified disease-free bud wood materials are of great importance. In the process of bud selection, it is required to ensure that clonal purity (freedom from sports and chimeras), good physiological vigour and high yield capacity are maintained and the bud material should be free from transmissible diseases. More than fifteen viruses are known to infect citrus trees in various parts of the world, and at least four of these, such as tristeza including seedling yellow strain, greening (a mycoplasma disease), exocortis and a strain of psorosis (Rao *et al*, 1975) have been reported to occur in India. Since the viruses can be easily transmitted through the bud wood, it is necessary to index the mother plant of bud wood sources for freedom of viruses and it can be done through the help of indicator plants, identified for expressing definite and clear symptoms for different virus--mycoplasma diseases. The standard indicator plants employed for the indexing are Kagzi lime, West Indian lime for tristeza virus ; sweet orange varieties like Pineapple, Valencia and Cucumber for greening diseases ; Etrog citron and Rangpur lime for exocortis virus ; sweet orange for psorosis virus and sweet lime and Orlando tangelo for xylopsorosis virus. The virus free bud wood obtained through indexing should be propagated and multiplied for further distribution. The mother plants raised from certified bud wood materials may act as future source of healthy bud-woods if they are grown in isolated areas free from virus infection, protected from further infection through control of insect vectors of various viruses. In case of mechanically transmitted viruses, where no known insect vector exists, frequent disinfection of propagation tools such as grafting/budding knife, pruning shears, etc., are essential for avoiding transmission of the disease. Through the use of nucellar clones of standard citrus varieties, the requirements of bud selections can be met to a great extent.

Raising of seedling for rootstock : It is desirable to raise citrus nursery in light, well drained but fertile soil, free from soilborne pathogens and nematodes. Bold seeds collected from desired trees may be sown in primary nursery beds properly prepared with enough organic manures. It is desirable that the upper top portion of the primary nursery beds are covered with sand (about a 3-5 cm layer) and the seeds before sowing are treated with fungicides to avoid seed-borne infections. Usually, 3-4 weeks' time is required for germination and when the seedlings attain 4-6 leaf stage, they are ready for transplanting in secondary nursery beds. In the secondary nursery, a proper spacing of about 20-30 cm is maintained between plants and rows and the off type seedlings of sexual or hybrid origin are eliminated. The elimination process ensures greatly towards getting true-to-type nucellar seedlings which are more or less uniform, upright and vigorous.

Budding technique : It is the most common method of vegetative propagation in citrus, particularly, in sweet oranges, mandarin oranges, grapefruits, etc. Different types of budding like Patch or Frokert or T-budding may be followed with high rate of success. The time of budding varies from place to place and the right stage of budding is when the plant has good sap flow and the cambium tissue is highly active. Well swollen unsprouted buds, from about one year old non-angular branches are preferred, and the presence or absence of small portion of wood along with the individual bud does not really matter for the success in bud union. Budding should preferably be done at a height of about 20-25 cm from the ground level and usually become ready for orchard planting in 6-9 months after budding.

Cutting and layering

In case of lemons, sweet lime, citron, etc., cutting and layering (air layering) are commonly employed in India and plants thus raised develop shallow but good root system. The operations are usually done during early rains and the propagating units become ready in about 3 months. After removal from the mother plants, it is preferable to keep the layers in the nursery bed for about a month before final transplanting at the orchard site. For certain specific advantages, however, budding on desired rootstocks may also be followed for these species as well.

Propagation of citrus through tissue culture

Studies on citrus tissue and organ culture *in vitro* were initiated during the last three decades. Gurgel and Sabrino (1951) successfully grew citrus embryos in Sach's medium. The technique of growing isolated citrus embryos in artificial media was described by Huresvili (1957). *In vitro* culturing of isolated vesicles stalks from *C. limon* was carried out successfully by Kordon (1963). Murashige *et al*. (1968) established callus culture from albedo and juice vesicles of *C. limon* fruit. Although callus was formed, it failed to differentiate. Nucellar isolated from monoembryonic varieties like Chandler pumelo and Temple orange, each gave rise to 10-15 embryos *in vitro* which developed into complete seedlings (Bitters *et al*, 1969). The plants arising from embrogenesis of the nucellus *in vitro* were found to be free from most of the pathogenic viruses (Bitters *et al*. 1972). Pseudobulbils, embryoids and other proliferation of varying size and form were obtained by culturing nucelli of various Clementine clones and lemon, bergamot and citron varieties on a media containing Murashige and Skoog's nutrient, supplemented with adenine or methylaminopurine. Many plantlets were obtained from Clementine and lemons but bergamot produced a few and citron none (Starrantino and Spina, 1977). Differentiation of callus tissue obtained from stem explants of *C. madurensis* into shoots and roots was recorded by Grinbalt

(1972). Chaturvedi and Mitra (1974) obtained rooted plants from isolated stem and leaf tissue of *C. grandis* and *C. sinensis*. Stem segments of different citrus species were cultured in different media supplemented with micro-nutrients and growth regulators, and significant success in obtaining rooted plants was recorded by Bhansali and Arya (1980) and Kitto and Young (1981).

Kochba *et al*, (1972) obtained whole plants by culturing 1-8 week-old ovules and nucelli of Shamouti and Valencia orange *in vitro* in Murashige and Tucker's nutrients supplemented with kinetin, IAA, coconut milk or GA_3 ; a higher kinetin/IAA ratio or addition of coconut milk favoured stem elongation more than root formation whereas lower kinetin/IAA ratio favoured root formation and inhibited stem elongation. Embryos, pseudobulbils and embryogenic callus were obtained *in vitro* culture of undeveloped ovules excised from ripe fruits of the Navel orange group and of lemon (Starrantino and Russo, 1980). Large number of seedlings were produced by subculturing the embryos, pseudobulbils and embryogenic callus on fresh MS media with added 6-methyl amino purine.

A micro-grafting technique was described by Tusa and co-workers (1979, 1980) ; success ranged between 25 per cent to 100 per cent depending on the stock/scion combination.

7.7 Cultivation

Planting

Usually, citrus is planted in pits of 50 × 50 × 50 cm or of 75 × 75 × 75 cm sizes in square system with a spacing of 5 to 8 m depending upon the species and rootstocks. For a dwarfing rootstock like trifoliate orange or a species like acid lime (*Citrus aurantifolia*) a spacing of 5 m × 5 m is considered to be adequate. For pumelos and grapefruits and for vigorous rootstocks like rough lemons or karna khatta wider spacing is usually recommended. In the north-eastern region of India, seedling-origin Khasi mandarin orange orchards are usually very closely spaced and in the old orchards, trees are found to grow even 2-3 metres apart in an irregular way. Mandarin orange being more or less upright in growth habit, particularly, when raised from seeds can be planted at a distance of 5-6 metres. Naik (1949) suggested a spacing of 7 to 8 metres for budded plants of sweet orange var. Sathgudi, lemons and pumelo. In Haryana conditions a spacing of 5 × 4·5 m was found to be optimum for Kinnow mandarin budded on jatti khatti (*C. jambhiri*) rootstock (Chundawat and Arora, 1981), while a closer spacing of 3 × 3 m was found to be unsuitable for Nagpur mandarin budded on rough lemons (Deshmukh *et al*, 1981).

Though the planting is usually done during the monsoon season, it is better not to plant at the time of heavy rains to avoid any waterlogging near the planting

pits. Weather should not be too wet or too dry at the time of planting. In case of lanky propagating plants, staking should be done and at post-monsoon period, the plant bases may be covered with mulches so as to conserve moisture in the rooting zone. Supplementary irrigation in the early years of planting is essential during the dry months.

Irrigation

Irrigation is of vital importance to citrus orchards and it is considered as one of the most critical cultural operations. Since soil acts as the reservoir of water and since the water holding capacity differs considerably among different soil types, the irrigation requirement also varies greatly from place to place. The coarse-textured sand or sandy loam soils store less water and hence in such soils more frequent irrigation is required. In finer-textured clayey or silty soils, on the other hand, more water is required to wet but the frequency of irrigation should be less. In addition to soil type, irrigation requirement will depend on the species, rootstock, age, bearing capacity, topography, water table position, rainfall, atmospheric humidity, temperature, etc.

In deciding irrigation application in citrus, the following points need to be considered :

(i) About 60-80 per cent of root activity in citrus is confined to first 60 cm top soil and citrus roots spread far beyond the vegetative spread of the trees. The zone of water application is important and required to be standardised for irrigation economy. Experimental evidence (Huberty and Richards, 1954) showed that there was no significant yield difference in treatments between wetting of 80 and 40 per cent rooting zones. Neither too much wetting of total root zone, nor wetting of a small percentage of root zone are desirable.

(ii) During the periods of rapid growth, flowering and fruit set citrus trees are sensitive to moisture stress. The fruit size usually gets reduced if moisture deficiency occurs frequently when developing fruits are on the tree. During spring and summer months, soils may be allowed to dry out somewhat but wilting should be avoided during bloom and fruit setting period.

(iii) Citrus trees are highly sensitive to excess moisture and waterlogging conditions. They require good soil aeration, and excessive irrigation may result in poor soil aeration leading to reduced growth and yield, predisposing the trees to root-rot and other diseases. Excess irrigation also results in the leaching of essential nutrients from soil as well as in accumulation of certain undesirable salts if the irrigation water is not of good quality. Citrus trees are sensitive to salinity and the total soluble solids in the irrigation water should not exeed 1000 ppm. Over-irrigation of citrus causes decline of orchards in many cases.

(iv) While irrigating, care should be taken so that the irrigation water does not touch the tree trunk directly and a dry area needs to be maintained near the tree trunk. Saturation of soil beneath the canopy and direct contact of

irrigation water with the trunk may predispose the tree to root-rot (*Phytophthora* sp.) and certain other diseases. Waterlogging, particularly, near the tree trunk can be avoided by providing mounds of earth around the tree trunk well below the bud union.

Time and quantity of irrigation

Time of irrigation can be determined by various methods. Usually through feeling of soils at rooting zone and by examining the general appearance of leaves for signs of wilting, irrigation water is applied. Irrigation should not be held back till usual wilting symptoms are apparent. Determination of soil moisture content of the areas occupied by roots gives a fairly accurate indication of irrigation need. Through laboratory determinations of moisture content of properly collected field samples and after comparing them with field capacity and wilting point values, time of irrigation can be regulated properly. The so called moisturemeters or tensiometers can also be employed for the purpose. Experimental evidences on citrus irrigation are very much lacking in India. Systematic trials conducted in the USA and certain other countries indicate that maximum fruit yield could be obtained by minimising or preventing moisture stress, particularly during the first part of growing season including fruit setting period. Certain amount of moisture stress during latter part of growing season, however, increased the soluble solids and vitamin C contents of fruit juice. Studies conducted in Maharashtra (Chinappa *et al*, 1977) indicate that water stress of 30 to 40 days' duration in December-January, followed by scheduling of irrigation after flowering at 50 to 75 per cent depletion of available soil moisture in clayey loam soil resulted in optimum yield and growth of Nagpur mandarin orange under hot, dry climatic conditions. From another study conducted in the same region of Maharashtra with 8 year-old Nagpur mandarin showed that moderate quantity of irrigation (1500 litres/tree) when applied at 120 cm from tree trunk resulted in better sized fruit and higher yield (Deole *et al*, 1977) Singh and Singh (1981) claimed that irrigation at 30 days' interval reduced the incidence of granulation in sweet orange var. Valencia Late by 20 per cent.

About the method of irrigation, Singh *et al*, (1961) suggested that young trees up to 8 years may be profitably irrigated by basin system. Other irrigation methods applied are flood, furrow and sprinkler methods. The application of irrigation in right time and in right quantity is more important than the method of irrigation. Usually, under North Indian condition weekly irrigation is provided during March to June and during November to February fortnightly irrigation is practised.

Manuring and Fertilisation

Citrus is a nutrient loving plant and about 15 elements have been known to have important role to play for proper growth and development of citrus. In

addition to the major nutrients like N, P, K, Ca, Mg and S, citrus requires micro-nutrients like Zn, Cu, Mn, Fe, B, Mo, etc. Inadequate plant nutrition causes serious disorder in citrus and may eventually lead to decline of the orchards.

Extensive work has been done on citrus nutrition and the mineral nutrition of citrus has been thoroughly reviewed by Smith (1966) and Chapman (1968). Chapman *et al*, (1945) reported that about 18 tonnes of citrus fruits remove about 21 kg nitrogen, 5 kg phosphorus, 41 kg potassium, 19 kg calcium, 3·6 kg magnesium, 2·3 kg sulphur, 40 gm boron, 9 gm copper, 50 gm iron, 13 gm manganese and 13 gm zinc. The figures amply demonstrate the essentiality of maintaining proper nutrient balance in the citrus orchards, so as to maintain desirable tree health and productivity. Since the nutrient availability and requirement depend on many factors like the species and variety, soil reaction, soil fertility, soil type, extent of leaching of nutrients and soil erosion, and on different climatic parameters like rainfall, temperature, etc., proper maintenance of fertility of orchard soils is somewhat a complex problem. Judicious fertiliser schedules for different locations can thus be worked out only through location based nutritional trials coupled with continuous determination of soil and leaf nutrient status.

Like many other crops, leaf has been found to be the most satisfactory tissue to analyse for diagnostic purposes and the nutrient status in citrus trees. Citrus leaf analysis technique has been well recognised for diagnosis of deficiencies, for determination of optimum fertiliser rates and for assisting in the interpretation of fertiliser trial results. Since many factors such as leaf age, season, growth cycle, variety and rootstock may influence the levels of nutrients in the leaf and since there may be interactions between mineral constituents in the leaf, for correct interpretation of leaf analysis the factors should be well considered. Smith and Reuther (1950), Chapman and Brown (1950), Cradock and Weir (1969) and others found that leaves of same age from different flushes do not differ greatly in mineral content and usually spring flush leaves of about 4-7 month-old are preferred for analysis. Some workers specify selection of leaves from fruit bearing terminals but investigations have shown that there are significant differences in nitrogen, phosphorus, potassium and calcium between leaves taken from behind fruit and leaves from non-fruiting shoots (Cradock and Weir, 1969). Usually, leaves from non-fruting terminals are used for determination of status of mineral elements. Chapman (1960), De Villiers and Beyers (1961), Reuther and Smith (1954) and others suggested standards for classification of nutrient status in citrus and after adopting and revising the values available from different sources, Smith (1966) proposed the following leaf analysis standard for sweet orange var. Valencia (Table 4). The proposed standard is based on concentrations of mineral elements in spring flush leaves of 4-7 month-old collected from non-fruiting terminals.

TABLE 4. STANDARD FOR CITRUS LEAF ANALYSIS (Smith, 1966)

Element	Ranges				
	Deficient less than	Low	Optimum	High	Excess more than
	In per cent of dry matter of leaf				
Nitrogen	2·2	2·2-2·4	2·5-2·7	2·8-3·0	3·0
Phosphorus	0·09	0·09-0·11	0·12 0·16	0·17-0·29	0·30
Potassium	0·7	0·7-1·1	1·2-1·7	1·8 2·3	2·4
Calcium	1·5	1·5-2·9	3·0 4·5	4·6-6·0	7·0
Magnesium	0·20	0·20 0·29	0·30 0·49	0·50 0·70	0·80
Sulphur	0·14	0·14-0·19	0·20-0·39	0·40 0·60	0·60
Sodium	—		<0·16	0·17-0·24	0·25
Chlorine	--	—	<0·2	0·3 0·5	0·7
	In ppm of dry matter of leaf				
Manganese	18	18-24	25-49	50 500	1000
Zinc	18	18-24	25 49	50-200	200
Boron	20	20-35	36 100	101-200	260
Iron	35	35-49	50-120	130-200	250
Copper	3·6	3·7-4·9	5 12	13-19	20
Molybdenum	0·05	0·06-0·09	0·10-1·0	2-50	100
Lithium	--	—	<1	1-5	12

Nutrient status of citrus orchards in India

Combination of field observations plus confirmatory chemical analysis of soil and leaves provide a realistic means of evaluating the nutritional status of citrus trees. Although some of the nutrient deficiency symptoms are clearly manifested in citrus, many a time the deficiency symptoms get mixed up with disease symptoms, particularly of some virus diseases. The analysis of leaf nutrient status gives a fairly good account of nutrient availability to the trees as well as helps in formulating the fertiliser schedules for different areas. In the recent past, extensive studies had been conducted on the nutrient status of existing citrus orchards in different parts of India and considerable information is now available.

In the north-eastern region, Ramamurthy and Desai (1946) recorded presence of excessive iron and low magnesium both in soil and plant ash, while Chowdhury and Dutta (1950) observed the symptoms of boron deficiency in the leaves of certain citrus species. Chowdhury (1954) also reported about wide spread deficiency of zinc in mandarin orange orchards of Assam. Prasad and Ghosh (1976) recorded that all soils in Meghalaya are high in organic carbon (>0·75 per cent) and low in available P and K. The contents of available phosphorus and

potash varied from 0·4 to 3·4 kg/ha and 14 to 76 kg/ha respectively. Surface soil of western and northern slopes of the Khasi Hills were rated to be low in available zinc but soils of all other places had adequate Cu, Fe and Mn. On the basis of the data on leaf nutrient status of existing mandarin orange orchards situated in the important belts of Meghalaya, Sikkim, Tripura and Arunachal Pradesh, Ghosh *et al*, (1981) observed that calcium and zinc were in low to deficient levels and iron was in excess universally in the entire area surveyed. Nitrogen was on the low side in most of the areas but the range of leaf nitrogen was quite wide (1·82 to 3·5 per cent). The P level ranged from low to high (0·1 to 0·28 per cent) and in most of the cases the concentrations of K varied from optimum to excess. The levels of Mn, Cu and Mg were optimum in the leaf samples.

Randhawa (1970) reviewed the nutrient status of soils and leaves of citrus orchards in Punjab, Haryana and Himachal Pradesh and observed that in general, nitrogen was deficient in all the citrus growing areas of these states. While available potassium in most of the soils of Punjab and Haryana is in the medium to high range, response of phosphorus can be expected in certain types of soil belts only. The leaf nutrient status indicated (Kanwar and Randhawa, 1960, Kanwar *et al*, 1963 ; Randhawa *et al*. 1967) deficiency of zinc, almost universally in the surveyed areas of these states, while iron and manganese were deficient in Ludhiana and Ferozepore belt of Punjab and Rohtak area of Haryana State. Sekhon *et al*, (1977) after analysing plant samples of sweet orange from Abohar and Bhatinda areas of Punjab observed that about 97 per cent of the samples showed deficiency of zinc, while in the declining trees, levels of zinc, boron and calcium were low. Malewar *et al*. (1977) reported low to optimum levels of zinc in the leaf samples of mandarin and sweet orange in Marathwada region of Maharashtra. From Andhra Pradesh (Karimnagar area) also deficient levels of zinc (6·4 to 16·4 ppm) were reported in the trees of sweet orange var Sathgudi whereas other elements like Cu, Fe, Mn, Ca, Mg, P and K contents were found to be adequate in the leaf samples. Survey of nutritional status of acid lime (*C. aurantifolia*) orchards in Rayalaseema region of Andhra Pradesh (Reddy *et al*, 1981) revealed that in Cuddaph district K, Cu and Zn were low, Mg and Cu were optimum and Fe was high. In Nellore district, K, Ca, Mg, Zn and Mn were low, P was optimum and Cu and Fe were high. In Chittoor and Kurnool districts K, Mn and Zn were low and other micro-nutrients were optimum. The tentative ranges of macro and micro-nutrient elements in the leaf samples collected from citrus orchrads located in different parts of Coorg region of Karnataka State have been reported from the Citrus Experiment Station, Gonicoppal of the Indian Institute of Horticultural Research (Table 5).

Role of major and micro-nutrients

Nitrogen : Nitrogen plays very key role in growth and production of citrus. Due to its deficiency the young leaves become undersized and develop light green

TABLE 5. RANGES OF MACRO AND MICRO-NUTRIENTS IN CITRUS IN COORG REGION

Nutrient element	Fruit bearing terminal	Non-fruit bearing terminal
Nitrogen (%)	1·82–2·48	2·00–2·79
Phosphorus (% P_2O_5)	0·21 0·30	0·21 0·35
Potassium (% K_2O)	0·98 1·79	1·04 2·49
Calcium (% Ca O)	4·13-5·96	3·33-5·85
Magnesium (%MgO)	0·50-0·80	0·40 0·78
Copper (ppm)	20–174	20-173
Zinc (ppm)	36–97	35-96
Manganese (ppm)	52 124	51–124
Iron (ppm)	100–155	103–171

to yellowish-green colour, general growth gets retarded and foliage sparse. Trees under severe deficiency for a prolonged period fail to produce commercial crops. Usually, soil containing less than 110 kg/acre of easily oxidizable nitrogen (N) are rated low in available nitrogen and are expected to respond to application of nitrogenous fertilisers. Nitrogen from nitrates is more quickly available to the plants and continued application of ammonium sulphate may increase subsoil acidity. It is advisable to apply soluble forms of nitrogen in split doses, particularly in the high rainfall areas, and it is commonly recommended that the half of the required nitrogen should be applied in the form of organic matter. Foliage spray of urea of low biuret content may be beneficial to a limited extent.

Phosphorus : Citrus appears to receive phosphorus more readily from the soil than many other plant species and phosphorus usually does not become limiting factor for citrus growing. Phosphorus deficiency leads to reduction of foliage density and causes deterioration in the physico-chemical characters of the fruits. Fruits usually becomes large with coarse and thick rind. Fruits from deficient trees are more acidic and prematurely soft.

Response of phosphorus fertilisation is clearly detectable only in the severely deficient areas, and in the highly acidic soils phenomenon of phosphorus fixation results in the non-availability of applied fertilisers to a great extent. In the acidic soils, rock phosphate containing free calcium carbonate may be used as phosphatic fertiliser, rather than the usual superphosphates. For correcting the deficiency, only the required dose should be applied, since excess of phosphorus may interfere in the absorption of zinc, iron and copper. It is advisable to apply phosphorus only after soil and leaf analysis.

Potassium : The deficiency of potassium causes chlorosis of mature leaves through fading of chlorophyll in blotches near the leaf apex or the margins, gumming of twigs, premature fruit shedding and reduction in fruit size.

Potassium deficiency can be corrected through soil application of fertilisers like potassium chloride, potassium sulphate, etc. Excess potash increases acidity in the fruit juice and should be avoided. Since in Indian soils potassium content ranges from medium to high, potassium should be used judiciously, otherwise it may even induce magnesium, manganese and zinc disorders.

Magnesium : Magnesium deficiency is chiefly associated with acid and highly leached soils and symptoms are commonly clear in fruit bearing limbs, particularly in the fruit maturing season. Yellow blotches start along the midrib of mature leaves and finally irregular yellow bands are observed on either side of the midrib. In acute deficiency, the entire tree looks yellow and leaf shedding takes place. Seeded varieties are reported to be more prone to magnesium deficiency and deficient trees are known to be more cold susceptible. Magnesium usually moves from the older leaves to new growth and developing fruits, especially of seedy varieties.

In non-acid soil, magnesium deficiency can be corrected by application of magnesium sulphate or magnesium carbonate in the soil, while foliar spray of magnesium nitrate is useful for quick action. If the soil is acid, application of suitable quantity of dolomite lime may help in improving the magnesium status.

Calcium . Calcium deficiency symptoms are not very distinct and the symptoms are rather rare under field conditions. Leaves on calcium deficient trees are usually smaller in size and somewhat thickened. Premature drop of leaves and die-back of twigs are associated with the deficiency of calcium. The deficiency can be corrected by the application of domestic lime or gypsum.

Sulphur : No clear-cut and distinct symptoms could be identified for sulphur deficiency and the requirement appears to be met indirectly through the N, P and K fertilisers carrying S.

Zinc : Zinc deficiency is considered as the most wide spread and damaging micro-nutrient deficiency of citrus. Deficiency symptom develops only in the new growth. The leaves are small-sized, chlorotic rather crowded on short stems, giving a bunched appearance. The chlorosis pattern is quite distinct, where the areas between main lateral veins become whitish yellow. Mild early stage of zinc deficiency resembles those of manganese deficiency and as the deficiency becomes more severe, the mottling becomes more pronounced, and twig die-back symptom starts appearing. In acute cases, there is considerable die-back of smaller twigs and the tree starts declining.

Zinc deficiency is controlled effectively by foliar spray of 0·4 to 0·6 per cent zinc sulphate. Zinc is absorbed by the leaves at any time during the year, but maximum benefit is obtained when spring flush leaves starts expanding. Soil applications of zinc salts have not proved very effective and in severe cases, repeated spray may become essential.

Manganese : Manganese deficiency is indicated when the immature growth is mottled with light green or yellowish-green areas between the major veins. The veins and small adjacent areas of the veins remain green and unlike zinc deficiency, the leave size remains unreduced. The deficiency symptoms are more pronounced on the shady side of the tree and shaded inside leaves show clearer symptoms. Only in case of severe deficiency chlorosis pattern persists in the older mature leaves. Since manganese deficiency frequently occurs in combination with deficiencies of zinc or iron, its symptoms are often over-shadowed. Defoliation, loss of vigour and lower yields are the results of severe manganese deficiency.

Manganese deficiency occurs commonly in acidic coastal soil, where manganese content is low and in alkaline soil, where manganese gets fixed in an insoluble form unavailable to the plant.

Manganese deficiency can be effectively corrected through foliage spray of 0·4 to 0·6 per cent manganese sulphate in spring or summer, when new growth occurs.

Copper : Copper deficiency is not associated with leaf chlorosis. In severely deficient trees, droplets of gum appear on succulent shoots, and pockets of dried gum are found in the twigs. In the fruits, gum pockets are present at the inner corners of the fruit segments next to the central pith. Oranges usually show scaby lesions on the rind, while lemons lack juiciness. Twig drying and die-back often occur. Where copper injury is not important, regular Bordeaux sprays are effective and deficiencies may be corrected through foliar sprays of mixture of copper sulphate (0·4 to 0·5 per cent), hydrated lime and water.

Boron : Foliar symptoms of boron deficiency are non-specific and definite diagnosis can be made only through leaf analysis. Usually, in boron deficiency, tree remains less vigorous with sparse vegetative growth and with abundant blooms. Fruits usually become hard, and brownish gum deposits are observed in the fleshy coat of the fruit. The central core or pith of the fruits may be gum soaked and seeds may abort and turn dark. Since the range of deficiency and toxicity is very narrow in case of boron, only soil and plant analysis can be used as a correct guide for boron application. Deficiencies can be corrected by foliar applications of 0·1 per cent borax or boric acid.

Iron : Iron deficiency, which is often called as 'iron chlorosis' or 'lime induced chlorosis', causes a pattern of fine network of green veins against a cream coloured or nearly white background of leaf lamina. In severe cases, the leaves become small, and twig and branch die-back occurs. Usually chlorosis becomes more pronounced during autumn and winter and in many cases only a single branch or a section of tree may be affected, while the rest remains normal in appearance. Normally, in calcareous soils with high pH iron deficiency occurs.

Iron deficiency has proved to be one of the most difficult to correct. The foliar application of iron is not useful for correcting the deficiency and application of costly input like iron chelate may help in controlling the deficiency. Irrigation

should be carefully managed since over-irrigation aggravates the deficiency. Different citrus rootstocks vary in their ability to take up iron. The trifoliate orange (*Poncirus trifoliata*) is known to absorb less amount of iron, while sour orange has better ability to do so. Cleopatra mandarin was found to utilise iron in alkaline soil, where drainage is not a problem.

Molybdenum : Molybdenum deficiency symptoms become conspicuous only in fully enlarged 3 to 4 month-old leaves, where light green spots appear. The spots are fairly small on mandarins, while in grapefruit the spots are larger in size. The leaves that show spots usually drop and as a result deficient trees assume thin and unthrifty look. Trees grafted on grapefruit are more prone to molybdenum deficiency. The deficiency can be corrected through foliar application of sodium or ammonium molybdate.

Manuring and fertiliser schedules in India

For sustained production and for maintenance of proper orchard health it is essential to apply manures and fertilisers to citrus orchards regularly. For non-bearing tree, fertiliser application may be done in an area more than drip circle, leaving 15-30 cm radius around the tree trunk. It is advisable to apply the fertilisers in split doses and application should be made when there is sufficient moisture in the soil. In the old bearing orchards, since the entire area becomes covered with citrus roots, fertilisers may be applied by broadcasting from trunk to trunk leaving about 30 cm around the tree trunk.

Micro-nutrients are usually supplied through foliar sprays. Better absorption and effects of foliar sprays are observed when the new spring flush leaves are half expanded.

Not much experimentally verified information is available on the specific fertiliser doses for different citrus species at different locations of the country. From the long term systematic nutritional trials conducted at the citrus Experiment Station of the Indian Institute of Horticultural Research located in the Coorg region of Karnataka, the manurial schedule recommended for Coorg mandarin orange has been given in Table 6.

In Punjab, nitrogen is found to be in deficient levels in all the citrus growing areas and based on the work done in the State, the following fertiliser recommendations have been made by the Punjab Agricultural University (Randhawa, 1970) :

Age of tree	Dose per tree		Fertiliser basis (gm)
	FYM (kg)	Nutrient basis (gm) (N)	Ammonium sulphate (20% N)
1-3 years	5-20	50-150	250-750
4-6 years	25-50	200-250	1000-1250
7-9 years	60-90	300-400	1500-2000
10 years and above	100	400-800	2000-4000

TABLE 6. MANURE AND FERTILISER APPLICATION SCHEDULE FOR COORG MANDARIN (KG per tree)

Manure/Fertiliser	Time of application	Ist Year*	2nd Year	3rd Year	4th Year	5th Year	6th & onwards
Cattle manure or farm yard manure (FYM)	February-March	—	5·0	10·0	15·0 to 20·0	20·0 to 25·0	25·0 to 30·0
Calcium ammonium nitrate/ Ammonium sulphate,	March-April	0·225 mixture	0·100	0·225	0·70	0·70	0·90
Single superphosphate,	—	—	0·225	0·450	0·55	0·55	0·80
Muriate of potash	—	—	0·065	0·140	0·20	0·20	0·20
Calcium ammonium nitrate/ Ammonium sulphate	June-premonsoon	0·225 mixture	0·350	0·700	0·80	1·00	1·00
Single superphosphate.	—	—	0·450	0·800	0·85	0·85	1·00
Muriate of potash.	—	—	0·065	0·150	0·30	0·25	0·30
Calcium ammonium nitrate/ Ammonium sulphate.	September-October	0·225 mixture	0·225	0·450	0·60	0·80	0·80
Single superphosphate.	—	—	0·225	0·450	0·60	0·60	0·70
Muriate of potash.	—	—	2·065	0·150	0·20	0·25	0·35
Dolomite/agricultural lime	—	—	1-2	2-3	3	3	3
Actual nutrient per year	—						
N	—	—	0·160	0·325	0·50	0·60	0·70
P_2O_5	—	—	0·165	0·310	0·38	0·40	0·50
K_2O	—	—	0·140	0·255	0·50	0·52	0·60

*Ist Year : A mixture of 1 : 1 : 0·5 prepared by mixing calcium ammonium nitrate ammonium sulphate, single superphosphate and muriate of potash.

Bajwa and Kaura (1952) reported that for 7-8 year-old sweet orange trees application of about 600 gm of nitrogen per tree in the forms of 50 per cent N as FYM plus 50 per cent as ammonium sulphate resulted in maximum fruit yield, and the yield increase with such treatment was about 60 per cent more in comparison to unfertilised control trees. They advocated application of farm yard manure in January and of ammonium sulphate in two split doses in mid-February and mid-April.

From the fertiliser trials conducted in a 15-year-old Khasi mandarin orchard of seedling origin situated in acid soils of northern slope of Khasi Hills, Meghalaya, Ghosh *et al*, (1981) reported that,

(i) a fertiliser dose of 300 gm N, 250 gm P_2O_5 and 300 gm K_2O per tree per year was found to be optimum for best economic yield ;

(ii) foliar application of Mg (2% magnesium sulphate) and B (0·1% boric acid) during the end of April before full expansion of spring flush leaf significantly increased the fruit yield ;

(iii) addition of different nutrients like N, P, K, Mg, Ca, Zn, B, etc., did not affect the fruit quality significantly ;

(iv) phosphorus nutrition appeared to play an important role for higher productivity and a positive correlation of leaf phosphorus status with fruit yield was observed.

Bose *et al*, (in press 1982) recorded marked improvement in yield and quality of fruits on declined trees of mandarin orange in Darjeeling district by using N, P, K and Zn and Cu.

For Andhra Pradesh (Anantapur and Pulivedala area) Reddy and Swamy (1977) found a manurial schedule of 2·25 to 2·72 kg N, 1·209 kg P_2O_5 and 0·25-0·37 kg K_2O per tree as optimum for high yield and better fruit quality of sweet orange. In Rahuri region of Maharashtra, a fertiliser dose of 800 gm N, 100 gm P_2O_5 and 400 gm K_2O per tree has been advocated for sweet orange var. Mosambi by Desai *et al*, (1981).

From a long duration (16 years) micro-nutrient trial with mandarin orange var. Coorg, Srivastava *et al*, (1981) reported that plants sprayed with Cu, Mn and Zn gave significantly higher fruit yield than the untreated control plants. No significant effects of addition of micro-nutrients like Cu, Mn, Zn, Fe, Mg, etc., on the fruit quality were apparent.

Under New Delhi conditions, Raturi and Mukherjee (1981) observed that three sprays of Zn (0·5% zinc sulphate neutralised with lime) were necessary for maintaining satisfactory level of Zn in all the growth flushes of 15 year-old sweet orange var. Hamlin trees budded on jatti khatti rootstock. Zinc sprays effectively controlled chlorosis and die-back symptoms, and through three foliar sprays of zinc sulphate plus 1 per cent urea a marked increase in fruit yield could be achieved over control in the second and third year. The chlorotic conditions and die-back in citrus could be effectively corrected by spraying with micro-nutrients such as

zinc and copper (Dikshit, 1958) ; zinc, iron and boron (Chowdhury, 1954 ; Aiyappa *et al*, 1961) ; molybdenum and boron (Aiyappa *et al*, 1959) and zinc, copper and iron (Kumar and Sharma, 1960) and zinc plus boron (Singh and Misra, 1980). Mann and Takkar (1981) found that foliar application of zinc sulphate significantly increased fruit size, fruit weight, total soluble solids and vitamin C contents in juice of sweet orange and claimed that unneutralised spray solutions of 0·15 and 0·30 per cent zinc sulphate were equal or more efficient than 0·45 and 0·60 per cent neutralised (with hydrated lime) zinc sulphate in increasing zinc concentration in leaf.

Micro-nutritional deficiencies of individual elements cannot always be ascertained through leaf analysis and visual symptoms indicating complexity in diagonisis of different micro-nutrient deficiencies. The following spray can be prescribed for chlorotic and declined trees once or twice a year : zinc sulphate 98 gm ; copper sulphate 59 gm ; manganese sulphate 39 gm ; ferrous sulphate 39 gm : borax 20 gm ; magnesium sulphate 39 gm and lime 180 gm dissolved in 20 litres of water.

Intercropping

In the early stages of establishment of a citrus orchard till bearing, the interspace can be economically utilised with short duration crops, preferably of leguminous types. Selection of intercrops is of utmost importance. Exhaustive intercrops which deprive the citrus trees of essential nutrients and moisture and the intercrops having intercultural requirements that are antagonistic to the requirements of citrus trees should be avoided. Undesirable intercrops can adversely affect the citrus plants through exhaustion of nutrients, deterioration of physical properties of soil, incompatible irrigation, root injury due to deep soil working, shading and by acting as the alternate hosts for diseases and pests. As far as practicable, the intercrops should be shallow rooted, of short duration, should have good canopy cover to protect the soil from erosion, profit yielding and non-soil depleting types. Bajwa and Ali (1945) observed that growing of crops like wheat, maize, jowar, bajra and sugarcane as intercrops have harmful effects on citrus in North India, while Ghosh *et al*, (1981) recorded that intercropping with maize, ragi, buckwheat and turmeric in the north-eastern hill region had undesirable effects on mandarin orange trees. Chadha (1970) opined that excessive and indiscriminate intercropping were one of the causes of citrus decline in Punjab.

Leguminous intercrops are usually considered as safe for citrus orchards, since they are less exhaustive and help in adding nutrient through nitrogen fixation. Crops like pea, cowpea, gram, beans are considered as safe intercrops. Usually the citrus growers who happen to be near the cities prefer to grow vegetables and fodder crops. due to ready market and better profit and in such cases, up to

prebearing age, pea, beans, tomato, etc., may be grown during rabi season and crops like cowpea, gourds (bottle and bitter), lady's finger, etc., can be cultivated as kharif crops. Fodder berseem as intercrop in citrus orchard has, however, been found to be unsuitable mostly due to its frequent irrigation requirement, which imparts adverse effect on citrus.

7.8 Flowering, Pollination, Fruit Set and Fruit Drop

Flowering

In citrus any bud is a potential fruit bud and flowering takes place mostly in spring and in growing season, when both soil moisture and temperature remains favourable. Although in acid group, limes, lemons, citrons, flower almost throughout the year, two major flushes of flowers usually occur in other species of citrus. The intensity of flowering is influenced greatly by the period of growth cessation, and the amount of the preceeding bloom or crop. In the North Indian conditions, where the temperature goes down substantially during winter months, major bloom of almost all the species occurs during early spring (February-March), when the atmospheric temperature starts rising after the cold winter, and soil moisture condition also improves (Hayes, 1970). In South India, where there is no well defined winter with very low atmospheric temperature, the flowering season is longer and not very distinct. It is very common to get two crops, occasionally three also, in many citrus types grown in South India (Naik, 1949). The flowering can, however, be regulated by withholding soil moisture, or through fruit thinning by chemicals and adjustment of fruit harvesting. The practice of withholding water from citrus trees as an aid to promote flowering may cause severe injury to the trees, and hence, use of chemicals is most desirable. In Israel, Eureka lemons sprayed five times with CCC at a concentration of 1000 ppm, SADH at a concentration of 2500 ppm or BOA at a concentration of 25 ppm considerably increased flowering and production of lemons (Monselise and Halevy, 1964, Monselise *et al.* 1966). BOA was found to be relatively more effective on branches that were older than six months, while CCC and SADH were found to be more effective on branches that were six months old or younger. Goren and Monselise (1969) found chloramphenicol succinate, 5-fluorodeoxyuridine and 5-bromo-3-sec-butyl-6-methyluracil to be effective in inducing flowering in orange. The increased bloom was accompanied by the shortening of internodes which is the characteristic of all flowering branches. Pruning seems to have little effect on time and amount of bloom.

The time of blossom bud differentiation has been found to differ from year to year with climatic variations and also from variety to variety within a species. A brief outline of the time of blossom bud differentiation in sweet orange varieties at different places is presented in Table 7.

TABLE 7. TIME OF BLOSSOM BUD DIFFERENTIATION IN SWEET ORANGE VARIETIES AT DIFFERENT LOCATIONS.

Variety	Locality	Time of differentiation	Reference
Pineapple	Florida, USA	January 29, 1929	Abbott (1935)
Pineapple	Florida, USA	January 18, 1931	
Pineapple	Florida, USA	January 12, 1932	
Washington Navel and Valencia	Griffith, NSW Australia	Early spring	West and Bernard (1935)
Valencia Late	Lyallpur (Pakistan)	January 31	Randhawa and Dhinsa (1947)
Sweet orange	China	3rd week of November	Lin and Wu (1957)
Washington Navel,	Japan	Middle of December to early January	Fujita and Yagi (1956)
Valencia	Japan	Late January	
Fukuhara	Japan	Early February	
New Summer	Japan	Middle of March	
Navel	Japan	January	Ito *et al*. (1950)
Blood Red	Pantnagar UP (India)	January 9, 1970	Babu and Kaul (1972)
Jaffa		Januray 24, 1970	

Pollination

In general, pollen development, is a normal phenomenon in citrus, excepting in a few important citrus varieties like Washington Navel, Satsuma mandarin, Bearss lime etc., where no viable pollen is produced. Variation in the longevity of pollen grains of different citrus species has been recorded by Capoor and Bajpai (1978). Nair and Singh (1969) observed that the pollen grains from mature buds of *C medica* had higher germination potentiality than the dehisced ones. The varieties where pollen is produced in abundance, self-pollination is a general rule. However, in orchard with mixed planting of different varieties, cross pollination is not uncommon. The stigma remains receptive for 6–8 days. Honey bees are known to act as the pollinating agent in citrus. Cross pollination is reported to increase seediness in certain citrus varieties like Shamouti orange, Clementine mandarin and Mineola tangelo and it has been reported that in the later two varieties cross-pollination has resulted in increased fruit yield. In Washington Navel and Marsh Seedless grapefruit also hand pollination with pollen from seedy varieties had been reported to cause better fruit set. Both male (e.g., Washington Navel, Satsuma) and female (e.g., Marsh grapefruit, Eureka and Lisbon lemons) sterility, partial self-incompatibility and normal male and female fertility conditions prevailing in the genus citrus which have resulted to different degree of seediness in the fruits and in general citrus fruits fall in the broad categories of —seedless (with no seed), commercially seedless (0–10 seeds per fruit) and seedy

(numerous seeds) classes. Self-incompatibility has been reported in several species of citrus such as Siamese pumelo (Aala, 1953), Orlando tangelo (Krezdorn and Robinson, 1958), Italior, Nepali Oblong and Lucknow Seedless lemon (Naidu, 1953), pumelo (Nauriyal, 1952), Clementine mandarin (Soost, 1956) and sweet lime (Singh and Dhuria, 1960), but Nagpur Santra was found to be self-compatible and cross compatible except with grapefruit (Kedar and Gopal Krishna, 1977).

Fruit set

In most citrus species, poor fruit set and high fruit drop result in poor yields, especially under unfavourable environmental conditions such as late frosts, drought or excessive rain, etc. During summer months there is considerable loss of soil moisture resulting in severe drop of fruits. Mulching with leaves (Krishnamurthy, 1959) or black polythene (Sinha *et al*, 1978) has been found to reduce fruit drop. Many growth regulators have been tried in citrus with varying degree of success. Stewart and Klotz (1947) and Erickson (1951) found no increase in fruit set and fruit size in Valencia orange by aqueous sprays of 2, 4-D. In contrast, Hield and Stewart (1956) obtained increased fruit set and fruit size in Washington Navel orange by aqueous sprays of 8 ppm 2, 4-D. A spray of 2, 4-D and 2, 4, 5-T has been found to increase markedly fruit set and improved the size and quality of fruits in mandarin (Singh and Randhawa, 1961). Titratable acidity, ascorbic acid and sugar content of the fruit increased as a result of treatments with 2, 4-D, 2, 4 5-T or NAA (Singh and Randhawa, 1961, Sinha *et al*, 1977). 2, 4, 5-T at 10 and 15 ppm increased fruit set over control in Pineapple, and Valencia Late orange (Sharma and Chopra, 1978).

Experiments conducted in California showed that an increase in fruit set resulted when GA_3 applied to flowers or to individual fruits of Bearss lime, Eureka lemon and Washington Navel orange (Hield, *et al*, 1958). In other investigations, gibberallin sprays had been found beneficial in Clementine mandarin (Soost and Burnett, 1961), Valencia orange (Coggins *et al*, 1960), grapefruit (Coggins *et al*, 1962, Chundawat and Randhawa, 1972), sweet lime (Randhawa *et al*, 1959), Jaffa and Pineapple sweet oranges (Randhawa and Sharma, 1962). Although increased fruit set has been achieved as a result of treatment with GA_3 some undesirable effects of gibberellin treatments on fruit quality was also recorded. Thus, gibberellin treated fruits have rough and thick skin and are less juicy as compared to untreated fruits

Fruit drop

High rate of fruit drop is a serious problem of citrus in India (Randhawa and Dhillon, 1965). Many chemicals have been tried to reduce fruit drop. While NAA was found ineffective in reducing fruit drop in Washington Navel oranges (Jones, 1951), 2, 4-D is very effective in reducing or preventing pre-harvest drop of

citrus, mainly because it delays development of abscission zone on the fruit stem. An application of 2, 4-D at a concertration of 8 ppm, when the Valencia orange fruits are 0·5 inch in diameter, reduce the drop of mature fruits (Stewart *et al*, 1952). Similarly, spray of 2, 4-D at 60 ppm applied in June or July will reduce fruit drop during summer or early fall (Hield *et al*. 1964). Investigations done at IARI revealed that 2, 4, 5-T (30 ppm) was effective in Jaffa and Mosambi and in Pineapple 2, 4-D (15 ppm) was most effective (Randhawa *et al*, 1961) when spraying was done in October. Similarly, GA_3 at 50 ppm and 75 ppm was effective in Jaffa and Pineapple respectively in reducing June drop (Randhawa and Sharma, 1962). Randhawa *et al*. (1959) found gibberellic acid, 2, 4-D and 2, 4, 5-T being effective in reducing fruit drop in sweet lime, while GA_3 and 2, 4-D proved effective in reducing fruit drop in Darjeeling mandarin (Bose *et al*, in press).

7.9 Pests and Diseases

Pests

Large number of species of insects and mites have been reported to attack citrus and more than 120 species could be recorded in India. In Punjab about 22 species could be recorded (Bindra, 1966 ; Singh and Sohi, 1957), out of which 14 species were found to be of importance. In the Kodagu area of Karnataka more than 50 species were found to damage citrus, while in the north-eastern region 51 species of insect-pests were found to be associated with citrus, mandarin orange in particular. The important citrus pests and their suggested control measures are :

Citrus psylla (*Diaphorina citri* Kuwayama) : It is a small (3-4 mm long) flying insect of grey colour, having broken brown band in the wings. A single female insect can lay about 800 eggs after the pre-oviposition period of about 24 hours. The nymphs hatch out after about 4-6 days in summer and 22 days in winter. The nymphs reach adult stage after 11-25 days and there is no pupal stage.

Citrus psylla attacks all species and varieties of citrus and the nymphs and the adults cause damage by sucking the plant sap. The nymphs suck the cell sap from tender shoots, leaves and flowers causing curling of leaves, defoliation and drying of twigs. The nymphs also secrete whitish crystalline honey dew which helps in the growth of fungi. The insect has been found to act as the vector for the 'greening' mycoplasma disease, and thus contribute in the decline of citrus orchards through direct damage and as indirect carrier of the serious disease.

The adult insects may live up to 6 months and there are about 10 overlapping generations in a year. As a result, population build up takes place within a short period of time, making the control of the pest quite difficult. However, some natural enemies, like five species of lady bird beetles, Syrphid fly, Chrysopa, certain

Spider mite were found to cause harm to the psylla. For controlling the insect through chemicals, spraying with Malathion (0·05%), Monocrotophos (0·025%), Carbaryl (0·1%), Phosphomidon (0·025%), Parathion (0·025%) and Malathion (0·03%) plus DDT (0·15%) have been recommended by various workers.

Citrus leaf miner (*Phyllocnistis citrella* Stainton) : It is a serious pest in the nurseries as well as in young and old orchards and has been found to occur throughout the country. It damages all citrus species and varieties.

The adults are minute silvery white moth with black eyes. The larvae usually mine the underside of leaves making serpentine mines, which are silver coloured because of entrapped air. The mining effect badly distorts the leaves resulting in their curling and defoliation during severe attack.

The adults lay about 62 127 eggs during 3 days of their life and the entire life cycle is completed in 14-21 days in May-August and 38-65 days during December March (Bindra, 1970). There are about 16 overlapping generations per year and during cool winter months populations are much reduced.

Weekly sprays of Monocrotophos (0·035%) during flushing periods or spray of Phosphomidon (0·03% EC) have been found to be effective in controlling the insect.

Aphids . Four species of aphids, namely, brown citrus aphid—*Toxoptera citricida* Kirkaldy (=*Aphis citricidus*), *Toxoptera aurantii* (black citrus aphid), *Aphis pomi* de Geer (green apple aphid) and *Myzus persicae* Sulzer (green peach aphid) have been reported to occur in citrus in India (Pruthi and Mani, 1945). However, the brown and black citrus aphids are more prevalent and cause major damage to citrus.

The aphids infest the lower surface of the leaves, tender shoots and young fruits. Curling of infested twigs and leaves are usually common. The black citrus aphid produces about five new ones daily for a period of one to three weeks. The species, *Toxoptera citricida* is an insect vector of tristeza virus, which is a very serious malady for citrus and which is responsible for citrus decline in many countries of the world. The virus may be transmitted even by migrating aphids without prolonged feeding on citrus.

For the control of aphids, insecticides like Oxydemeton methyl (0·025%), Monocrotophos (0·025%), Parathion (0·03%), Methyl demeton (0·03%) and Phosphomidon (0·035%) have been found to be effective.

Scales : Citrus scales, the sap sucking insects, are immobile in the adult stage and are of two distinct types- armoured scales, which have hard cover separate from the body providing protection to the body underneath, and soft scales, which have no separate cover, but sometimes a hard skin or a protective waxy secretion. Pruthi and Mani (1945) reported 49 species of scales on citrus in India.

Most of the armoured scales are damaging to fruit as blemishes at low levels of infestation and in severe cases, they damage the tree badly. Armoured scales do not excrete honey dew and there is no association of sooty mould fungus with them. The soft scales, on the other hand, are not as damaging as armoured scales and excrete honey dew on which sooty mould fungus grows. The scales have a few natural enemies like wasp parasites, predatory lady bird beetles, caterpillars and lacewing larvae, which may help in restricting scale infestation in citrus.

The scale insects can be classified as :

(a) *Armoured scales* (family—Diaspididae) :

(i) Red scale (*Aonidiella aurantii* Maskell) : The cover of adult females are circular, flattened, orange to red in colour, and the body under the scale is somewhat conical or pear shaped.

(ii) Florida red scale (*Chrysomphalus aonidum* L.) : Cover of adult females are circular and female body under the scale is yellowish in colour.

(iii) Yellow scale (*Aonidiella citrina*) . Very similar to red scale but less damaging, shade loving species. Usually found on undersides of leaves on lower and inner branches. Yellowish-brown in colour.

(iv) Oriental yellow scale (*A. orientalis* Newstead) · Female usually circular with about 2 mm diameter, yellowish-brown in colour.

(v) Glover's scale (*Lepidosaphes gloverii* Packward) : Scale cover of 2·5–3 mm long, thin and parallel sided. Female deposits eggs beneath the scale cover in two rows.

(b) *Soft scales* :

(i) Soft brown scale (*Coccus hesperidum*) : Mature scale is flattened, ovoid, mottle brown to pale yellow in colour, having a waxy parchment like upper skin. The mature female deposits a few larvae beneath her body each day over one to two months and several generations of soft brown scale develop during the year. It infests foliage and young twigs and produce honey dew copiously, resulting to sooty mould association.

(ii) Soft green scale (*Coccus viridis* Green) : Adult female is ovate, about 3 mm in length and pale green in colour. Each adult female gives birth to 300-500 young ones (crawlers), which settle in young leaves, twigs and fruits. Adult females live for 2-3 months and there are four overlapping generations. Sooty mould association is very common with the insect.

It is difficult to control hard armoured scale insects with insecticide sprays. Soft scales, however, can be controlled effectively by spraying Parathion (0·03%) emulsion, Dimethoate plus kerosene oil @ 150 ml plus 250 ml, respectively in 100 litres of water, Carbaryl 0·05 per cent plus 1 per cent oil, Malathion (0·1%), etc. Single application of systemic insecticide like Monocrotophos (0·1%) can

also control soft green scale. Spray of organophosphorus (like Rogor) plus oil sprays can keep the red, yellow scales under control.

Mealy bugs (*Pseudococcus filamentosus* Cockerell, *Planococcus citri* Risso.) : Mealy bugs are closely related to scales and have been reported from various parts of the country. The body of the insect is segmented and is covered with white mealy wax. Mealy bugs suck plant sap and may cause fruit drops. It also secretes honey dew on which sooty mould develops. Mealy bugs can be considerably controlled through similar sprays as recommended for citrus scales.

Citrus bark borer (*Inderbela tetraonis*, *Inderbela quadrinotata*) : The bark and shoot borers are serious pests in citrus, especially in neglected and old orchards. The caterpillars feed on bark and thus destroy the translocating tissues of the bark. Since they feed at night, they generally escape notice but their presence on an infested tree is indicated by the presence of hanging loose mass of fine pieces of woods and pellets of excreta, mixed with silky adhesive materials on the branches and stem of the tree.

The caterpillars can be controlled by inserting kerosine, petrol, carbon disulphide or chloroform plus creosote (2 : 1) into their holes and plugging the holes with mud. Removal of webbing, followed by painting or spraying of bark all round the damaged portion with BHC (0·5% suspension) or Paris green has also been found to be effective in controlling the insect.

Citrus trunk borer (*Monohomus versteegi*) : Very damaging pest of mandarin orange in Assam and other north-eastern region states. The grub bores into the trunk near the tree base and makes tunnels near the pith. The tree dies eventually due to infestation. The insect can be controlled by injecting petrol or carbon disulphide into the bored holes and plugging them with wet soil. Pruning and burning of severely infested branches along with the grub will help in checking the population build-up of the insect.

Similar other borers, such as lime tree borer (*Chelidonium cinctum*), orange shoot borer (*Obera lateapicalis*), orange stem borer (*Chelidonium argentatum*), orange beetle (*Stromatium barbatum* Fabr), etc., have also been reported from various parts of the country. Multiplication of borers can be checked by keeping the orchard clean, treating the soil around the tree with Aldrin or BHC, by painting trunks with DDT and by spraying with chemicals like Methyl parathion (0·05%) or Endosulfan (0·05%), Carbaryl (0·2%), etc., during oviposition periods.

Citrus or lemon butterfly (*Papilio* sp.) : Several species of the genus *Papilio* have been reported to occur in different parts of India, of which *P. demoleus* is the most common and serious species. The caterpillars are brownish or black in colour with irregular whitish stripes at young stage. The fully grown caterpillars are about 4-5 cm long and green in colour. The caterpillars feed on the leaves and defoliate the branches. Ordinary nursery stocks and young trees are badly

damaged by the insect which often feed on fruit stalk causing fruit drop. Hand picking of larvae, dusting of BHC (5%) or spraying with Sevin (0·1% WP) may be helpful in controlling the insect.

Citrus white flies: About 30 species of citrus white flies have been reported throughout the world, out of which a few species like *Aleurocanthus husaini* Corbett (Hussain's white fly), *A. spiniferus* Quaintance (orange spiny white fly), *A. woglumi* Ashby (citrus black fly), *A. citrifolii* Corbett, *Dialeurodes citri* (Ashmead), *D. elongata* are important in India. The adults of white flies are minute creatures with mealy wings held over the body in a roof like manner. The adults and the nymphs suck the juice of the leaves and as a result the leaves turn pale. Due to secretion of honey dew, sooty mould also develops on the leaves. The intensity of attack is more on the shady sides of the tree and dry hot summer adversely affects the nymphs of the insect.

Several species of parasites (*Eretmocerus* spp., *Prospaltella* sp.) and predators (*Brumus suturalis*, *Scymnus* sp.), etc., are natural enemies of citrus white flies as the larvae and adults of these parasites and predators feed on white fly eggs and nymphs. Pruthi and Mani (1945) recommended biological control and advocated even the sprays of suspensions of entomophagus fungi for the control of white fly. According to Bindra (1970) effective control can be achieved by spraying a 0·03% emulsion of Isobenzan, Parathion or Endrin, which should be more effective than the earlier practice of DDT 0·1 per cent suspension spray.

Fruit flies: Fruit fly infestations have been recorded from limited areas of comparative cooler and wet zones. In Coorg region of Karnataka, the incidence of oriental fruit fly (*Dacus dorsalis* Hendel) had been noticed in citrus orchards intercropped with coffee. By making punctures in the rind of semi-ripe fruits, the female inserts 2-15 eggs at a time and about 200 eggs are laid in a period of a month. The maggots develop in the fruit pulp and such fruits usually drop prematurely. Secondary infections of fungus and bacteria in the punctured fruits results in fruit rottening as well. In Sikkim and certain other north-eastern region states, fruit flies sometimes cause very serious damage of mandarin orange through premature fruit falling.

The fallen infested fruits are to be destroyed for reducing the insect population. Use of poison baits in the orchards starting about two months before harvesting of fruits help in controlling the insect and the control of oriental fruit fly could be achieved by applying bait spray containing Malathion or Trichlorfon spray or Fenthion (0·05%) plus crude sugar (1%).

Mites: Three species of mites have been considered as major pests in citrus and according to Ghai (1969) 13 species of mites have been found to be associated with citrus in India. The insects feed on the leaves, produce multiple grey spots, weaken the leaves and cause defoliation. In Punjab, the common citrus mite is a species namely, *Eutetranychus banksi* Pritchard and Baker whereas from South

India two mites namely red spider mite (*Tetranychus fijiensis* Hirst) and oriental red mite (*E. orientalis* Klein) have been reported to occur. The species like *Tetranychus sexmaculatus* and *T. telarius* were found to be prevalent in Assam. The species like *E. banksi* can be combatted by spraying 0·02% emulsion of Malathion, Parathion or Carbophenothion (Sethi, 1967).

For control of red spider mite and oriental red mite, insecticides like Monocrotophos (0·05%) and Dicofol (0·05%) have been found to be effective.

Fruit sucking moth : Fruit sucking moths, belonging to different genera (*Otheris, Achoea, Calpe, Anua, Ophideres*, etc.,) cause some damage by sucking juice of citrus. Ripe fruits of sweet orange, mandarin orange and sweet limes are commonly attacked. The insects pierce the fruit rind and expose it to secondary infections of diseases and infestation to flies. The fruit usually drops within a few days and thus becomes unmarketable. It is claimed that through elimination of alternate host plant from the vicinity of citrus orchards the insect infestation could be reduced considerably. Disposal of fallen fruits, which attract the moths, may also help in reducing the insect population. Baiting with Malathion (0·05%) with crude sugar and fruit juice also helps in controlling the citrus fruit sucking moth.

The other citrus insect pests of lesser importance in India are citrus stinkbug (*Rhinchocoris humeralis*), white ants (*Odontotermes obesus* R), red tree-ant (*Oecophylla smaragdina* Fb.). Thrips (*Thrips hawaiiensis* Morg), etc. The importance of citrus psylla and aphids, which have been recorded as vectors of greening mycoplasma and tristeza virus respectively, has attained significance in the recent past and the combating of these insect vectors are very essential to check further spread of these deadly mycoplasma-viral diseases of citrus.

Diseases

Large number of diseases have been reported to occur in citrus. Fawcett (1938), Knorr, *et al*, (1957), Wallace (1959) dealt with the disease problems of citrus elaborately, while citrus diseases of India and their association with citrus decline or die back complex have been reported by Reddy (1968), Raychaudhuri *et al*, (1969), Fraser (1966), Chohan and Knorr (1970), Nariani and Singh (1972), Capoor (1975) and others. The diseases can be caused by viruses, bacteria and fungi and the important diseases with their suggested control measures are discussed below :

Virus Diseases

Tristeza (Quick decline) : Tristeza (a word that describes the sad appearance of a tree) virus caused disastrous effects to the citrus industry in Argentina, Brazil, USA (California), etc., and between 1930 and 1950, more than 20 million citrus trees were lost due to infection of this disease. The lime disease in Gold Coast,

bud union decline in Australia, stem pitting of grapefruit in South Africa, tristeza in Brazil, quick decline in California and podredumber de las raicillas in Argentina, all were found to be caused by tristeza virus and its related strains. Fawcett and Wallace (1946) reported that 'quick decline' a disease of sweet orange on sour orange rootstock was caused by a virus transmitted by tissue grafts, while Meneghini (1946) showed that tristeza was caused by a virus transmitted by oriental citrus aphid, *Toxoptera citricida*. In India the experimental evidence of the presence of the virus was first reported by Vasudeva and Capoor (1958), although the presence of the virus was suspected much earlier. Also, six species of aphids were found to act as vectors of the virus in India (Capoor, 1975).

Tristeza virus particles are approximately 2000 m/μ in length and 10 12 m/μ in diameter and the virus is believed to remain in the phloem tissue only.

In the infected trees, leaves develop various deficiency symptoms, and leaf falling, root decay, twig die-back and ultimate death of the tree are also conspicuous. Affected trees have a tendency to blossom heavily in the off-season. Specific symptom of tristeza infection is honey combing, pitting of the inner face of the bark of the trunk, severe pitting develops in the species like lime (Mexican Key lime, Indian Kagzi lime), citron, *Citrus pennivesciculata* Tanaka, etc., while in sweet orange, mandarin orange, rough lemon, sweet lime, etc., stem pitting is usually absent. The definite test for the presence of tristeza requires greenhouse assay through indexing on indicator plants like Indian Kagzi lime, Mexican lime, etc., where definite symptoms of vein clearing and stem pitting confirms the presence of the virus.

The disease can be kept under control by use of tolerant rootstocks such as rough lemons, sweet orange, Cleopatra mandarin, Rangpur lime, trifoliate orange, citranges, etc., and by avoiding the uses of susceptible rootstocks like sour orange, sweet limes, etc. The bud wood to be used for propagation should be free from the viruses and through insecticidal spray the aphid (vector) population can be reduced considerably. In the recent past, certain milder strains of the virus could be isolated and attempts have been made to cross-protect the seedlings against the severe strains through inoculation of milder strains, particularly in case of acid lime. Standardisation of such pre-immunisation techniques for other commercial citrus species and varieties may be of much practical significance.

Greening : Greening, a comparatively new malady, is wide spread in many species of citrus and is considered by many as the second most serious disease. The disease is caused by a new group of organism known as mycoplasma and not by a virus as believed earlier.

The infected plant shows chlorosis of leaves resembling zinc deficiency (sometimes dotted with green islands), thickening of leaf blade, shortening of twig internodes, off-season blooming, leaf shedding and die-back. The chlorosis is usually bound on one side of the midrib and on another side by a lateral vein.

The chlorosis diffuses towards the leaf margin. Fruits of the infected trees are usually small-sized, lopsided, remain green for longer period, contain curved columellas, aborted seeds and fall prematurely.

The disease can be spread through infected bud wood and the insect vector, citrus psylla (*Diaphorina citri*). The presence of the disease could be confirmed through indexing on indicator plants like sweet orange varieties Valencia, Pineapple, Navel orange, etc., or through chormatographic techniques developed by Schwarz (1968).

The infected trees are required to be removed for checking further spread of the disease. Control of the insect vector through pesticides and use of certified disease free planting materials are the measures to be adopted to keep the disease under check. It has been claimed to achieve temporary recovery from greening disease through injection of certain chemicals like Tetracycline. The presence of the disease has been confirmed in almost all the major citrus growing belts of India (Fraser, 1966, Nariani *et al.* 1967, Ghosh *et al.* 1980).

Xyloporosis (Cachexia) : Citrus species that are susceptible to xyloporosis virus are tangelos, sweet lime, kumquats and mandarins. The virus causes the development of peg like outgrowths from the inner face of the bark that fit into corresponding pit like depressions in the wood. Gum pockets develop in the bark. The virus is bud transmissible and no insect vector is recognised. Through use of seeds or raising budded plants from disease free certified bud sticks on tolerant root-stocks, the disease can be kept under control. So far, it is not an important disease in India.

Exocortis (Scaly butt) : The virus in bud is mechanically transmissible, but no insect vector is known. It is carried symptomlessly in sweet orange, mandarin orange, grapefruit and rough lemon but very distinct bark-scaling symptoms appear in the trifoliate orange and in some of its hybrids like citranges. Rangpur lime and certain citrons have also been reported to be susceptible to the virus. So far the disease is not that serious for citrus industry in India, but with more use of rootstocks like trifoliate orange, citranges, Rangpur lime the disease can pose threat, if proper precaution is not taken in time. The presence of the disease in India had been confirmed by various workers.

Infected trees on susceptible rootstocks are stunted and show bark scaling, mostly in the rootstock portion.

Since the virus is transmitted through infected bud wood or mechanically through contaminated budding knives and pruning shears, use of disease free scion material, avoiding susceptible rootstocks and disinfecting the budding knives, pruning shears, etc., are some of the useful recommendations for control of the disease.

Psorosis (California scaly bark) : Psorosis is not a serious disease in India and unlike the other viruses that cause bud union related troubles, psorosis affects

citrus varieties irrespective of the rootstock used. The infected trees show leaf flecking in young leaves, and certain strains cause scaling of bark in the branches and trunk regions. For confirming the presence of the virus through indexing, sour orange, sweet orange, mandarins, Mexican limes can be used as indicator plants. No insect vector could be found so far. It is essential to destroy the infected plants and use certified disease free bud wood materials for propagation.

Other viral disease

In addition to the above mentioned disease, there are quite a good number of other viral diseases which cause considerable damage to citrus. The diseases like stubborn (acorn) occurring in USA and Mediterranean countries, bud-union crease reported from USA, South Africa, Venezuela, Brazil, Egypt, etc., woody gall (vein evation), tatler leaf, Satsuma dwarf, yellow shoot (Li-ku-bin), petrifaction, etc., are of some importance in different countries of the world but of little or no concern in India presently.

Fungal Diseases

Phytophthora rot (foot rot, collar rot, crown rot, root rot, brown rot, phytophthora gummosis) : Out of the several species of the genus *Phytophthora*, three species namely, *P. parasitica* Dast., *P. citrophthora* Sm and Sm Leonian and *P. palmivora* Butler (reported to occur in India), have been found to cause very serious damage to citrus plants. The fungi are soil inhabitants and flourish well under high moisture conditions. Citrus trees exposed to wet soil for an extended period are more prone to phytophthora infection. Phytophthora rot disease has been reported from almost all the major citrus belts of India and is considered the most serious and most damaging fungal disease of citrus in the country.

Phytophthora disease produces symptoms of decline in citrus trees through rotting of rootlets, girdling of the tree trunk and defoliation. The first symptoms are dark staining of the bark and the invaded bark is at first light olive brown in colour, firm, with a water-soaked appearance. The fungus affects the bark and can penetrate a limited way into the wood. In advanced stages, the bark cracks, shreds in length-wise strips as it dries and gum starts exuding, particularly in the late spring. Yellowing and die-back of limbs above the injury occur after the disease is well advanced. Lemons, sweet oranges, grapefruits and mandarins are highly susceptible, while the rootstocks like sour orange, Cleopatra mandarin, trifoliate orange, Rangpur lime, etc., have been found to be tolerant.

Raising of nursery stock in phytophthora free conditions, avoiding stagnation of water around tree trunk and good drainage provision, painting of Bordeaux paste on the trunk up to about 50-60 cm, use of tolerant rootstocks and high budding at about 30 cm above ground levels are some of the preventive measures

to be adopted for escaping the disease. In case of infection, if the disease can be detected before the bark covering more than half of the circumference of a stem is damaged, scarping of the affected portions with a little extra healthy tissue without injuring the wood and application of Bordeaux paste (1 : 2 : 16-20 water) or Bordeaux paint (1 : 2 : 3 linseed oil) on the scarped as well as healthy portions around the infected zone, may help in combating the disease and recovery of the plant.

Powdery mildew (*Oidium tingitaninum* Carter) : Powdery mildew is a common disease of citrus in India On infection whitish powdery growth develops on the young leaves (both sides) and twigs. The affected leaves get distorted in shape and reduced in size. In case of severe infection, leaf falling, premature fruit dropping and die-back symptoms become apparent.

Warm and humid weather favour the growth of the fungus and usually during spring and autumn the disease symptoms are more severe.

Dusting of sulphur powder (200-250 mesh) or spraying of wettable sulphur (1 kg in 200 litre of water) can control the disease, if applied at the initial stage of the disease. In case of severe infection, repeated application of the fungicides like Bavistin or Calyxin may be essential.

Pink disease (*Corticium salmonicolor* Berk and Br) or *Pellicularia salmonicolor* (Berk and Br) Dastur : Pink disease has been reported from different parts of the country and besides citrus, the disease infects other species like rubber, coffee, cocoa, tea, cinchona, mango, cashew, jackfruit, etc.

In the early stages of infection, branches and leaves start drying and the affected branches get covered with fine silvery white mycelium which later turns pink in colour. Brownish discolouration of the bark and wood and shredding of bark into longitudinal strips are noticed in the infected trees. Desiccation, chlorosis, dropping of leaves and final drying of twigs are commonly observed, during August to October, when the disease usually appears.

Pruning and burning of diseased branches and spraying of Bordeaux mixture (1%) or other copper fungicide like Blitox (0·2%) may control the disease.

Scab (*Elsinoe fawcetti*) : Scab disease, which is often confused with bacterial canker, has been reported to cause limited damage to citrus, through development of corky lesions on fruits, leaves and young twigs. The leaves with severe infection become distorted, wrinkled and infected fruits become hard and often drop prematurely. This is one of the major disease in the hilly tracts where low temperature and high humidity prevail. In the north-eastern hill region and parts of West Bengal the disease is commonly observed in the mandarins, citrons, lemons, etc.

Removal of infected leaves, twigs, fruits and spraying of Bordeaux mixture or 0·3% Blitox have been found to be effective in controlling the disease.

Felt disease (*Septobasidium pseudopedicellatum* Burtt.) : It is a common disease of Assam and other north-eastern states and of limited occurrence in other parts of the country. In case of infection, the twigs and branches get encircled by soft felt-like leathery fungal growth, which may extend up to the petioles and leaf bases and fruit stalks. The causal fungus remains on the surface and below the felt like growth colonies of scale insects thrive.

Usually, older and weak trees in neglected orchards are infected and in north-eastern region of India mandarins (Khasi orange), pumelo (Robabtenga), Adajamirs (*C. assamensis* Dutta and Bhatt), Assam lemon, etc., are commonly attacked by this fungus.

Clean cultivation and spraying of Bordeaux mixture along with crude oil emulsion are recommended for keeping the orchard free from the disease.

In addition to the above diseases, certain other fungal diseases like damping off (*Pythium, Rhizoctonia* spp.), wilts (*Fusarium, Verticillium* spp.) are common in the nurseries, while leaf fall and fruit fall (*Phytophthora palmivora*), sooty mould (*Capnodium citri*), wither tip or anthracnose (*Colletotrichum* spp.), melanose (*Diaporthe citri*), ganoderma root rot (*Ganoderma lucidum*), mushroom root rot (*Armillaria* sp.), dry root rot (*Macrophomina, Fusarium, Diplodia* spp.), etc. have been reported to occur in certain areas. Proper orchard management, clean cultivation and spraying of certain general fungicides like Bordeaux mixture may keep most of the diseases under control.

Bacterial disease

Citrus canker (*Xanthomonas citri* Hasse Dowson) : Citrus canker is widespread in India and is a very serious disease in acid lime. The disease is caused by a germ negative bacterium which affects all above ground plant parts like leaves, twigs, fruits and thorns. The canker lesions appear as minute water soaked roundish spots which enlarge slightly and turn brownish and corky. A yellow brown halo surrounds the lesion, particularly in the leaves. The size of the lesion varies from host to host ; on acid lime and sweet orange they are about 2–3 mm in diameter whereas on grapefruit leaves the diameter may even reach 15 mm. Several lesions may coalesce to form a patch. The disease can spread by splashing of bacteria-laden drops of water falling on leaves, twigs and fruits during rains and even through winds. Citrus leaf miner insect also indirectly helps in the spread of the disease. The infected fruit gets less market value and in severe cases become even unmarketable.

Pruning and burning of diseased twigs, specially before monsoon, protective spraying of 1 per cent Bordeaux mixture to emerging flushes or application of streptomycin sulphate (500 ppm) are recommended for control of the disease. Control of citrus leaf miner is also essential to reduce the incidence of the disease.

7.10 Harvesting

Stage of maturity

The various physico-chemical parameters of maturity were found to be influenced by agro-climatic conditions and the cultural practices, and the maturity standards vary from region to region (Devkota *et al*, 1982) in the different citrus species. A remarkable feature of Kinnow fruit growth is characterised by its sigmoid growth pattern (Pal *et al*, 1977). while the growth of sweet orange was reported to be linear (Jawanda and Bajwa, 1961). Kinnow showed a continuous increase in fruit diameter, reaching its maximum by the end of December whereas sweet orange fruits ceased growth beyond November 30th in case of Mosambi and December 15 in pineapple. Valencia on the other hand, after a steady increase in growth up to December 15, showed further increase during February-March (Jawanda and Bajwa, 1961). In Kinnow, the colour break occured much before the maturity was reached (Devkota *et al*, 1982). The period from last week of January to mid-February was considered optimum for picking Kinnow it was under Hoshiarpur (Punjab) condition. In the hills of Darjeeling district the mandarins are harvested from mid-November to late-December depending on the altitude. The fruits ripen earlier at lower altitude. The fruits may be retained for sometime after ripening for supplying late fruit. For early market, the orange at lower altitude is often harvested with the appearance of colour on the skin. Lemon and limes are harvested when almost fully developed but the skin is green. Studies on maturity standards in Kinnow at Palampur (Joolka and Awasthi, 1980) revealed that fruit size remained constant after 5th January, while the percentage of juice and TSS became constant after 25th January whereas acidity decreased as the maturity advanced. TSS/acid ratio was considered to be fairly a good index of maturity in most of the citrus fruits (Solue *et al*, 1967). Jawanda *et al*, (1973) reported this ratio to be 12 : 1 and 14 : 1 respectively for inner and outer fruits of Kinnow mandarin.

The fruits of Satsuma mandarin when mature are light to deep orange in colour and the surface becomes pebbled and bumpy (Srivastava *et al*, 1972). Shankar (1972) observed that the fruits of New Zeland grapefruit mature late and become ready for harvesting by the last week of November. The fruits can be kept on the tree till first week of March without any granulation, which fetch better price. The fruits of tangelos ripen by the middle of December and the fruits can be retained on the tree without any granulation till the last week of January (Shankar, 1973). Gupta *et al*, (1974) reported that rind of grapefruits differentiates from green to pale yellow as the fruit advances towards ripening.

Method of harvesting

In most of the citrus species, the fruits remain fresh for several weeks without any detoriation after attaining full maturity (Hayes, 1970) which facilitates

harvesting according to ones choice and demand in the market. In India, the fruit picker collect the fruits manually by climbing on a ladder when the tree is tall, with a collecting bag on his shoulders. In Japan, fruits are collected with scissors and in order to convey the harvested fruits from orchard to road, cableways are used (Singh, 1966). Small motor-handcart and motor-rearcar are also used, and recently conveying machines, such as monorail conveyors and roller conveyors, are being used. In the USA, mechanical harvesting systems consisting of abscission chemicals, shakers, windrover and pick-up machines are used, particularly for processing industry.

Post-harvest handling of fruits

After the fruit is taken into the packing shade, it is carefully washed as soon as possible. In California, the growers use a fungicidal cleaning solution of 0·5 to 1·0 per cent soap and 2 per cent soda or 0·5 to 1 per cent sodium-O-phenyl-phenate, dipping fruits for 4 to 5 minutes. After light brushing and washing, the fruits is dried, re-waxed and polished with soft brushes in order to substitute the natural wax coat lost in washing.

7.11 Yield

The yield of citrus varies not only in the different types and varieties but it also varies in a particular variety with age, care and management, location, and the rootstock used. Ramachandar *et al*, (1979) found low yield every 2nd or 3rd alternative years of high yield in Coorg mandarin. The fruit yields (number of fruit per plant) in several groups and varities of citrus in Punjab recorded by Chohan *et al*, (1966) are given below

Tangelos :			Tangerines		
vars.	Orlando	212	vars.	Dancy	540
	Pearl	173		Honey	302
	Minneola	127	Hybrids		
			vars.	Kinnow	131
				Wilking	282
Sweet orange					
var.	Cambell Valencia	128			

The average yield of grapefruit in New Zealand, was 400 fruits per tree (Shankar, 1972) while it was 600-700 for tangelo (Shankar 1973) under Allahabad condition. A healthy plant of mandarin orange, 15-20 years old produces 350-500 fruits, higher yield is not uncommon. Neglected orchards yield much less and the fruit size is also reduced (Bose *et al*, in press). Sulladmath and Iyer (1981) recorded an yield of 10·23 kg fruit per plant in Seville lemon, while Bhan (1972) reported a variation in yield between 600 and 1500 fruit per plant of Kagzi lime.

7.12 Packaging and Transport

In India, the harvested fruits are graded roughly according to size and appearance, mainly by the wholesalers near the centre of production. The growers, in most cases, sale the fruits much before harvest. Aiyappa and Srivastava (1965) suggested that the fruits should be polished lightly with a piece of cloth and individually wrapped in tissue paper. Rapid packing after harvest should be done where high temperature and low relative humidity tend to cause excessive loss of moisture from the harvested fruits (Naik, 1949). In India, citrus fruits are usually packed in wooden boxes for transportation to the distant markets inside the country, while for nearer markets bamboo baskets of various shapes are used. Chopped straw and dry grass are mostly used for padding. Excessive moisture loss aggravates the problem of distortion in long distance shipments (Grierson, 1973), which can be reduced by placing the fruit in individual cells. Ventilation is an important criteria in cartons stacked in register developing a forced air system (McDonald and Camp, 1973). The ventilation holes must be at the bottom and top of the container, not at the sides. (Barmore and Grierson, 1983).

In Florida, standard citrus boxes measure 12 × 12 × 12 inches and in California the orange boxes measure $11\frac{1}{2} \times 11\frac{1}{2} \times 24$ inches whereas in Australia the standard size of orange boxes is $18 \times 10\frac{1}{2} \times 11\frac{1}{2}$ inches.

In India, citrus fruits are still transported by rail or by road as ordinary cargo and without refrigeration which often leads to heavy loss due to decay and fungal infections. Refrigerated vans or continuous air flow arrangement should be used for distant transportation of citrus fruits. Now-a-days shrink films for moisture loss control are of use with more advantages (Ben-Yehoshua, 1978). The technique consists of individually wrapping of fruit in polymeric films, 0·5 – 1·0 mils in thickness, and then shrinking the film to the shape of the fruit with heat. For longer transit and/or storage, specified refrigeration temperature may have to be less than optimum for decay inhibition and to avoid chilling injury. Barmore and Grierson (1983) suggested the following transit and storage temperature for citrus fruits.

Types	Temperature 0 C Transit	Storage
Oranges	10·0	0 – 1·1
Grapefruit	10 0 – 15·5	10·0 – 15·5
Lemons, Limes	10·0	10·0
Mandarins	10·0	4·4

7.13 Storage and Ripening

Storage

Citrus fruits can be stored well for a few days at room temperature, and through cold storage preservation techniques most of the citrus fruits can be

stored for several months without any appreciable detoriation in marketable quality. Since the peel of the fruits plays an important role in regulating physiological loss, the extent of moisture loss during storage, is not same for citrus fruits of different species. The optimum storage temperature that ensures the longest storage life with minimum spoilage of fruits and their quality also varies considerably with different types of citrus.

Green and fully ripe yellow fruits of mandarin orange could be stored successfully at 8-10 °C under 85-90 per cent relative humidity without impairing the fruit quality (Srivas *et al.* 1965). Eaks (1976) found that orange could be stored for 12 weeks at 5 °C, but storage at 0 °C caused chilling injury. Tahiti limes could be stored well up to 2 months at 6 °C, but over 7 °C they lost their green colour within 4 weeks (Bleinroth *et al.* 1976) and for 6 weeks at 10 °C or 15·6 °C and 98-100 per cent relative humidity without yellowing (Spalding and Reeder, 1976). In case of Kinnow mandarin, 2·2-3·9 °C temperature was found best for storing with polythene wrapper for 60 days (Singh, 1981). The most suitable temperature for storage of Kagzi lime was 18° C (Bose *et al.* 1968). Pekmezii (1983) reported that the 10 °C temperature and 85-90 per cent relative humidity was found to be the best storage condition for Kutdiken lemon. Under such condition, it was possible to store this variety without losing much quality for a period of 8 to 9 months from its harvest. Cold storage with intermittent warming promoted long term storage of lemons for 6 months or even more (Cohen, 1983).

Treatment with different chemicals have also proved effective in extending the storage life of citrus. Mann and Randhawa (1976) observed that wax coated Kinnow mandarins remained fresh without much loss in weight. In orange, Lodh *et al.* (1968) observed delayed maturity by treatment with, 2, 4-D. Application of Ethrel at 1000 ppm and storage at 24-28 °C in 68 per cent relative humidity enhanced the colour development with lower chlorophyll content and reduced *Penicillium* infection in mandarin (Rahana *et al.* 1973). The sweet orange fruits treated with Aureofungin (100 ppm) and Bavistin (0·2%) could be stored for 68 days without any spoilage (Ghosh, 1980). The period of storage of Eureka lemon increased by treatement with 2, 4-D and, 2, 4, 5-T in wax emulsion (Stewart *et al.* 1952), in Persian lime 2, 4, 5-T was very effective (Halton, 1953). Treatment with MH markedly prolonged the storage period in Kagzi lime (Bose *et al.* 1968).

Ripening

Delay in ripening is caused by gibberellin or auxin treatment and Ethepon enhances the process. Monselise (1975) observed that application of GA_3 delayed colour and softness of peel but did not influence internal maturity due to the peculiar structure of the citrus fruits. Treatment with GA_3 prolonged the picking season of lemons (Coggins and Hield, 1968), and prevented early senescence of peel in Shamouti orange (Monselise and Sasson, 1977) also reduced

peel disorders of different varieties of oranges and mandarins. Pre-harvest treatments with Ethepon to promote colour and ripening are not used in citrus, because, while promoting colour, Ethepon does not influence internal composition of the fruit and causes excessive leaf abscission (Monselise, 1983). Citrus differs from typical climactric fruits and an increase in respiration does not change fruit colour and quality after harvest (Ables, 1973). However, ethylene increases the respiration rate in citrus at various stages of maturity, and an increase in both respiration and ethylene production has been noted when young oranges were removed from the tree (Eaks, 1970).

Citrus fruits often attain internal ripeness while the peel is still green. The conventional degreening procedure is to use ethylene gas (Weaver, 1972). Lemons dipped in Ethepon at a concentration of 1000 ppm attained a marketable yellow colour within 7 days after treatment, while 50 ppm Ethepon was found to be optimum for ripening of grapefruits, tangerines and orange.

7.14 Marketing

Like many other fruits, marketing of citrus is also not properly organised in India. Small growers usually sell the fruits in the local market or to a local agent and the price is not remunerative. Fruits of many orchards are sold through auction after flowering or fruiting. The agents may again sell the fruits on the tree to another agent at a profit. As a result, the growers are deprived of a fair price The agents or contractors do not take adequate care while harvesting the fruits and the plants are often badly damaged.

Although some standards have been worked out for mandarin and sweet oranges on the basis of size, stage of ripeness and external appearance, in general no uniform marketing standard is followed in most parts of India. In Japan, almost all the citrus growers are members of the cooperative associations and they bring their fruits to the grading and packing houses managed by the associations (Singh, 1966). In India, cooperative channels are gradually developing for encouraging the citrus growers and several cooperative socities are now in operation in Punjab, Haryana, and Maharashtra. Recently, in West Bengal the National Dairy Development Board has been purchasing mandarin from cooperative societies and selling in Calcutta along with milk. It has not only provided better price to the grower but has also helped in developing an awareness for increasing the production of good quality fruits by proper care and management.

7.15 Breeding and Varietal Improvement

Considerable work has been carried out in citrus breeding and quite a large number of hybrids within and between six genera, i.e., *Citrus*, *Poncirus*, *Fortunella*, *Microcitrus*, *Eremocitrus* and *Clymenia* have been successful (Swingle and Reece,

1967). Since in citrus most of the characters are inherited qualitatively, breeding is much complicated by heterozygosity (Spiegel-Roy and Vardi, 1982) and by self and cross-incompatibility, which occur in a number of citrus variety. Presence of series of self-incompatibility alleles in pumelos and their hybrids, in grapefruit hybrids like Mincola and Orlando and Clementine mandarin have been reported. Even with such limitations citrus breeding remains to one of the major areas of improvement primarily due to the availability of rich germplasm, their wide range of variability and high degree of success of interspecific and even intergeneric crosses.

Selection of superior seedlings are of immense importance. Several good varieties like 'Kiyomi' tangor and the triploid grapefruit 'Oroblanco' have been evolved (Soost and Cameroon, 1981). In general, triploids tend to low fruit yields (Cameroon and Frost, 1968). Tetrapolids may arise spontaneously as nuceller seedlings but are of no economic interest, because they are often very slow growing in habit (Barrett and Hutchinson, 1978).

Breeding programme with specific objectives like producing early maturing citrus fruits with high yield and fruit quality, developing rootstocks having disease resistance, wider adaptibility, suitable for commercial cultivation of lemon, etc., are of considerable importance.

In rootstock breeding the main emphasis has been given on development of rootstock resistant to tristeza, *Poytopthora*, nematodes, etc. Most of the breeding programmes make use of *Poncirus* which is a carrier of resistance to tristeza, *Phytophthora*, nematodes and coldhardiness (Spiegel-Roy and Vardi, 1982), salt tolerant rootstock has also been found. possible in some progenies involving Cleopatra and Sunki mandarin and Rangpur lime, (Furr *et al*, 1963).

Hybridisation work was also undertaken to evolve hybrids of Kagzi lime resistant to canker along with other desirable characteristics by using seedless lemon, citron, kumquat, mandarin and Rangpur lime : on screening, some of the F_1 hybrids were reported to be resistant or highly tolerant to cankar disease (Chakrawar, 1981). Another breeding effort in Florida emphasised crosses between sweet orange and *Poncirus* to obtain varieties with orange type fruit, which were also found to be resistant to tristeza (Barrett, 1981). Spiegel-Roy and Vardi (1982) evolved a selection from Wilking×Valencia, which was found to be of precocious bearing habit with high total soluble solids, colour, and other characters were considered desirable for fruit processing.

Fruits of triploids with a few seeds are considered to be desirable types for table purpose. It has been reported that occasionally the chromosome of diploid parents became double and some of the resulting tetraploid embryos survived. Such tetraploid plants had been used as seed parents for producing triploids. The triploid embryos can be germinated satisfactorily by using *in vitro* technique. Plants have also been raised from anthers in *Poncirus* (Hidaka *et al*, 1979). This may prove important for genetic studies and for mutagenesis.

Among 43 species and varieties tested for greening diseases at Ludhiana, only four species namely, Amilbed, Gajanimma, Florida Rough Lemon and karna khatta were negetative for marker substances, indicating their tolerance to greening as they do not usually get infected under natural conditions (Anon, 1977). The highest incidence of marker substances were observed in species like sweet orange, mandarin, tangelo, rough lemon, chinotto, citron, nasnaran, '*Citrus macroptera, C. macrophylla, C. taiwanica* and *C. pectinifera* in which all the trees tested were positive indicating their high susceptibility to greening, while the hybrids such as Sacaton citrumelo, Carrizo and Troyer citranges and Kinnow were found to show marker substances only in 50 per cent of the tested trees.

Somatic mutations are common in citrus and through selection of the natural mutants quite a few number of desirable clones have been obtained. Mutations when occur in single somatic cell often perpetuate in only a part of the tissue and such partial mutants or chimeras have also been reported to occur in citrus. The frequent occurrence of chimeras may lead to clonal impurity and thus bud selection work in propagation becomes important for ensuring clonal purity. Some of the most important citrus varieties thus arose by somatic mutation. The homohistons variants like Redblush grapefruit was reported by Cameroon and Frost (1968) and certain heterohistons like Shamouti orange by Spiegel-Roy (1979). Selections of natural mutants (Iwamasa and Nishiura, 1981 ; Hensz, 1981 ; Russo, 1981) have been successfully employed on seedlessness ('Iyo' tanger), season of ripening ('Satsuma', 'Navel') improvement of colour ('Ray Ruby' grapefruit), etc.

In Japan, a few closely related clones of Satsuma mandarin with varied fruit colour and fruit ripening times could be obtained through mutations. In USA also mutations had produced Sastuma seedling lines differing in productivity, fruit shape and the ripening time. The grapefruit clones like Thompson and Foster Pink arose as limb sports on white grapefruit. Gamma irradiation of seed and bud wood performed in Orlando, Florida, resulted in seedless fruit on certain trees of seeded varieties like Pineapple orange as well as Duncan and Foster grapefruit. Vardi and Spiegel-Roy (1978) developed Shamouti trees of compact habit and early fruiting, and seedlessness in Eureka lemon by irradiation of bud wood with gamma-rays.

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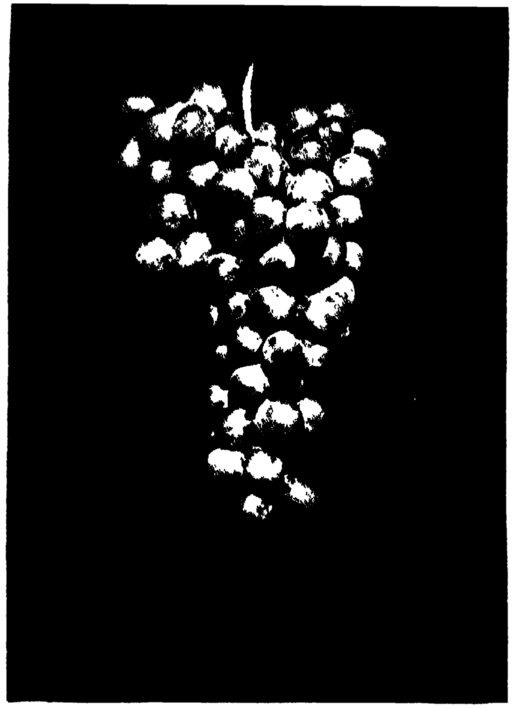
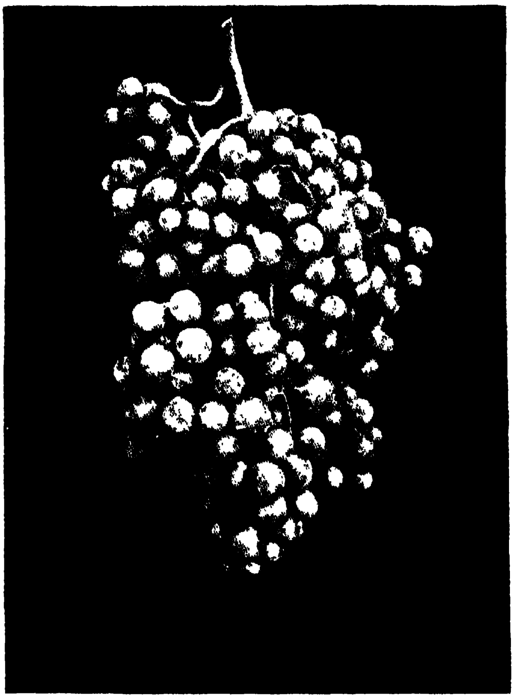
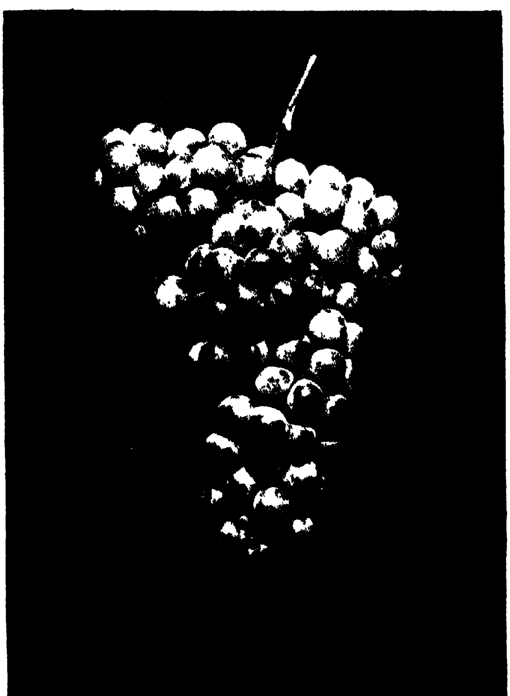
Making of a trunk girdle



Grape: var. Himrod



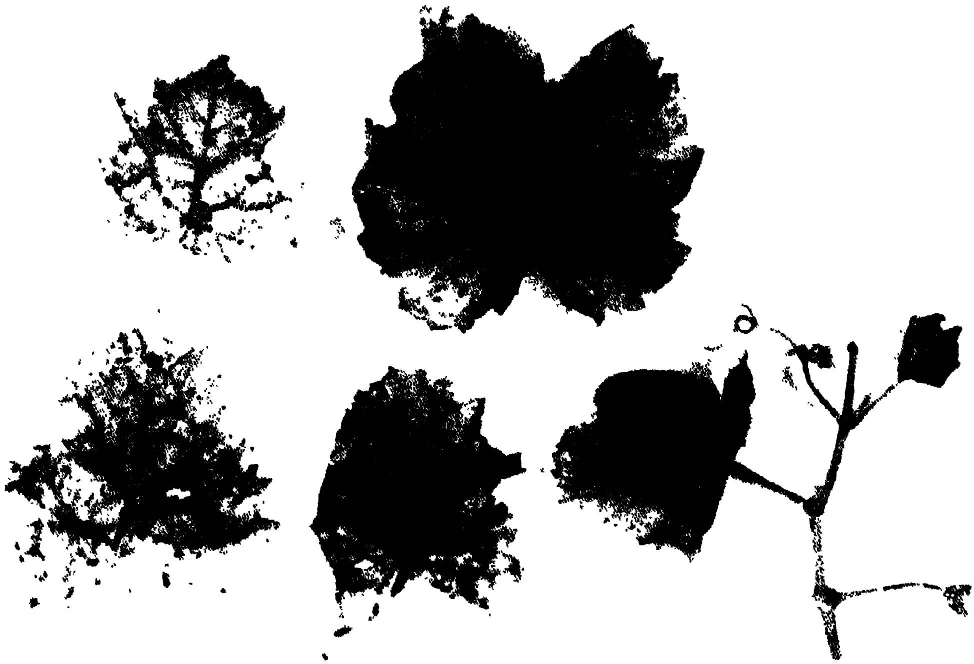
Grape: var. Hur



Grape: var. Perlette

Grape var Beauty Seedless

Powder



Anthracnose of grapes

Telephone-trained Pusa Seedless grape vine in bearing

8

GRAPE

P. C. JINDAL

The grape is a cultivated plant of antiquity as is evident by references in the Bible and other old authentic literatures. Its association with man is older than that of wheat and rice. Its great age is confirmed by fossil leaves and seeds discovered in deposits. The cultivation of grape is a very ancient art. Documents concerning viticulture and wine-making in Egypt dates back to some 5000 to 6000 years. Certainly before the beginning of the Christian era, grapes and wine had considerable importance to the Middle Eastern and Mediterranean people. The exact evidences of grape cultivation in India are not available. However, the mention of grape has been made in the medical treatises written in the 1st century A.D. in India. Now, its cultivation has become one of the most remunerative farming enterprises of the present time and the area under grapes is fast increasing in North as well as in South India.

8.1 Composition and Uses

The content of physical and chemical components of fruits depend upon the stage of development right after set up to ripening. In the succeeding paragraphs, the physical and chemical constituents of ripe fruits will be discussed and the periodic changes during development will be taken up at an appropriate place. Different environmental factors such as temperature, soil fertility, moisture, light have distinct influence. Growth and vigor of the vines and rootstock used have their own significance. The relative and absolute amounts of physical and chemical components of a ripe fruit vary much between the varieties (Franzy, 1959). Therefore, the general range of variation in these components is indicated here.

Physical composition

In grapes, the fruits are borne in clusters which consist of peduncle, cup stems, rachis and berries. The berry consists of skin, pulp and seeds.

The stems of the cluster include the rachis and its branches, and pedicels. The contribution of stem towards total weight of cluster at maturity is 2-6 per cent depending upon the variety. Great differences in between varieties occur in the length of stem parts, toughness, strength of pedicellar attachment and the thickness, and the rate of drying after harvest. Drying and browning of pedicels increase berry shatter during transit and storage.

The seeds generally constitute about 0 10 per cent of the weight of fruit. In crushed grapes (must) the seeds consist of 0–5 per cent (Amerine and Joslyn, 1970). The grape berry normally contains four seeds originating from four ovules, two in each loculus. However, the number of seeds may be less than four or even nil depending upon the abortion of ovules. Seedlessness is a special significance in raisin and table grapes. The grape seeds are rich in tannins (5–8%) and oil (10 20% of the weight of seeds). The oil content in two of the common Indian varieties (Anab-e-Shahi and Kali Sahebi) ranges from 10 13 per cent (Hameed *et al*, 1972).

The skin of the berries consists of epidermis and is composed of layers of thick-walled cells. This accounts for 5-12 per cent of the total fruit weight. The skin is covered with wax-like layer known as cutin or bloom which constitutes 1-2 per cent of total skin weight. The toughness of the skin provides resistance to handling injury in packing, transport and storage and the ease in which berries can be dehydrated to make raisins. The juice content depends upon the pulpiness of the variety, stage of ripeness, size of berries, seedlessness and the efficiency of extraction. juice content normally varied from 80 to 90 per cent of crushed grapes. A tonne of grapes produce about 681 to 738 litres of wine depending upon variety, type of processing and other factors.

The ranges of more important physical components of fruits are given in Table 1.

TABLE 1. THE RANGE OF PERCENTAGE OF THE PHYSICAL COMPONENTS IN RIPE FRUITS (by weight).

	Per cent	Remarks
Stem (rachis, branch, pedicel)	2-6	
Seeds	0-10	0–4 seeds per berry rich in tannins (5–8%) and oils (10 20%) 0-5% in must.
Skin	5-12	Cutin or bloom constitutes 1-2% of total berry weight
Juice	80–90% of crushed grapes	Depends mainly on the pulpiness of the variety

Chemical composition

The figures on the chemical composition of freshly extracted juice are available. Ranges of important organic and inorganic components of the fresh juice are shown in Table 2.

TABLE 2. COMPOSITION OF GRAPES (RANGE IN PERCENTAGE OF MORE IMPORTANT ORGANIC AND INORGANIC COMPONENTS OF FRESHLY EXTRACTED JUICE (by volume).

	Per cent		Per cent
Water	70-80	Residual	0·01-0·02
Carbohydrates	15-25	Mineral compounds	0·03-0·6
Dextrose (glucose)	8-13	Aluminium	0·003 (T)
Levulose (fructose)	7-12	Boron	0·007 (T)
Pentoses	0·01-0·10	Calcium	0·004-0·025
Pectin	0·01-0·10	Chloride	0·001-0·010
Inositol	0·02-0·08	Copper	0·0003 (T)
Organic acids	0·3-1·5	Iron	0·003 (T)
Tartaric	0·2-1·0	Magnesium	0·01-0·025
Malic	0·1-0·05	Manganese	0·0051 (T)
Citric	0·01-0·10	Potassium	0·15-0·25
Nitrogenous compounds	0·03-0·17	Phosphate	0·02-0·05
Protein	0·001-0·01	Rubidium	0·001 (T)
Amino acids	0·017-0·11	Silicic acid	0·0002-0·005
Humin	0·001-0·002	Sodium	0·020 (T)
Amide	0·001-0·004	Sulphate	0·003-0·035
Ammonia	0·001-0·012		

Source : Amerine *et al*, (1972)
T : indicates traces

Sugars : The sugars of *Vinifera* grape are primarily dextrose (glucose) and levulose (fructose), generally accounting for 99 per cent or more of carbohydrates in the must (crushed grapes) and from 12-27 per cent or more of the weight of the mature fruits. In addition to glucose and fructose, several other sugars are present in small amounts in grapes such as sucrose, raffinose, stachyose, melibiose, maltose and galactose. The main sugar translocated from the leaves to fruit is sucrose but small amounts of other sugars, especially raffinose and stachyose may also be involved in carbohydrate movements (Kliewer, 1965c). Once sucrose reaches the fruit it is hydrolysed by invertase (Hawker, 1969b).

Most of the sugars in the berries are manufactured in the leaves. Another source of sugars in grape berries is from transformation of organic acids (malic acid and tartaric acid), however, the percentage of the total sugars in grapes formed in this manner is quite small.

Acids : Tartaric and malic acids constitute 90 per cent or more of the total acidity. Citric acid being third most abundant acid in grapes constitutes only 0·02 to 0·03 per cent. There are more than 20 other non-nitrogenous organic acids in grapes in small amounts. The amount of free tartaric and malic acids in berries decreases markedly during ripening.

It is now well known that both leaves and fruits are capable of synthesising malic and tartaric acids. Leaves are known to export organic acids in the phloem tissue to other parts of plants (Kurasanoce, 1962).

Tannin : Tannins are complex esters of phenolic acids and sugars. These occur primarily in skin, stem and seed of grape. Its content influences the palatibility of grapes and their products. However, in minute to small amounts, these add to flavour. Singleton (1966) found 3770 mg/kg total phenols (as gallic acid) on an average in mature berries of 12 varieties studied. The tannins gave an astringent taste. Seeds, which contain tannins, if crushed while extracting juice also give astringent taste to the wine. However, tannins in wine stabilise the colour and aid in fining.

Nitrogenous compounds : Ammonium cations and organic compounds such as amino acids, hexose, amines, peptides, nucleic acids and proteins constitute the major part of nitrogenous compounds in grape berries. Total nitrogen in must (crushed grape) ranges from 10 to 200 mg per 100 ml (Hennig, 1955). Seven nitrogen fractions namely total nitrogen, protein nitrogen, ammonia nitrogen, phospho-tungstic nitrogen, amino acid nitrogen, humin nitrogen and amide nitrogen have been estimated (Hennig, 1943). The amount of amino acids differ considerably depending upon variety, location, maturity, cultural conditions and method of extraction.

Minerals : The mineral contents of grapes which constitute 0·2 to 0·6 per cent of fresh fruit weight are taken from soil. Most of the minerals are present in traces. Apart from the elements shown in Table 2 traces of bromine, iodine and fluorine are also found in grapes.

Vitamins : Fresh grapes contain many vitamins. Fairly good amount of vitamin A is present which is retained in dehydrated grapes. However, natural raisins contain no vitamin A. The B-complex vitamins of grapes are thiamine, riboflavin, pyridoxine, pantothenic acid, nicotinic acid, inositol, biotin and folic acid.

Joshi *et al*, (1976) studied vitamin C content of eight varieties and found the maximum in Madeleine Royale being 13·50 mg per 100 ml of juice.

Pectin : These are derivatives of polygalacturonic acid. Pectic substances are normal constituents of fruit. During ripening, the protopectin, which is found most abundantly in the primary cell wall, is transformed to pectin and the berries soften as a result of removal of middle-lamella pectate. *Vinifera* grapes contain smaller amounts of pectin as compared to American grapes which form stable jelly.

In addition to above discussed chemical constituents of grape berries, certain other compounds are also present which are responsible for imparting specific colour, odour and flavour. Some enzymes bring about biochemical reactions during the development of berry and synthesis of different chemical components.

Colour : Generally, the pigments of grapes are found only in skin where it is confined to the outer 3 or 4 layers of cells. Fruits of some red or black varieties, such as Salvador, when ripe or overripe, the inner cells of the skin rupture and exude colour, so that the pulp, especially near the skin becomes coloured. In another variety Alicante Bouschet juice is coloured in both skin and pulp. The pigments of grapes are anthocyanidins (red, blue, purple and black colour) modified by attachment of a molecule of glucose. There are five anthocyanins --cyanidin, delphinidin, petunidin, peonidin and malvidin--that make up basic part of grape pigment. The yellow pigment of both white and red grapes, is quercetrin--a flavone—and its glycoside, quercitron a flavanol. The oxidation of these pigments gave varieties an amber blush. The anthocyanin content ranges from zero, in a variety devoid of skin pigment to a maximum of about 2500 to 3000 mg/kg in variety line Alicante Bouschet (Singleton and Esay, 1969). It should always be kept in mind that it is the brightness, not the density of colour that makes table grapes more attractive. In cluster transfers by approach grafting, it was clearly proved that the synthesis of pigments is entirely independent of the leaves of the particular variety.

Odorous constituents : During ripening, grapes develop some volatile compound which emit a special aroma for a particular variety. Some varieties have distinct aroma, such as Muscats and foxiness of Concord. The substance responsible for the later has been isolated and identified as methyl anthranilate. Likewise, odorous constituents of Muscat of Alexandria have been isolated (Webb and Kepner, 1957). Muscat aroma is the most pronounced aroma of many *vinifera* varieties.

The substances responsible for aroma odour are largely confined to the skin of berries and are synthesised in the berries itself. However, the precursor materials are produced in the leaves which has been proved by cluster-transfer trials with approach grafting.

Flavour : It is the complex reaction of taste and olfactory receptors. Many substances contribute to flavour of which sugar, acids and tannins are dominant. Their relative amounts and not the total amounts determine the flavour. The tannins influence the astringency and thereby, its flavour.

Enzymes : Polyphenoloxidase is the main oxidizing system of grapes which is mainly confined to the skin. Other enzymes such as phenolase, phosphatase, proteinase and sucrase are also found in skins and to lesser extent in pulp. Polyphenoloxidase and catalase activities are found more in late and early ripening varieties respectively (Golodriga and Pu-Chao, 1963).

Selvaraj *et al*, (1975) studied the activity of catalase, peroxidase, pectinesterase, amylase and invertase at different stages of berry growth in Anab-e-Shahi variety of grape.

Uses

The world production of grapes exceeds that of any other fruit crop. The fruit is utilised in many ways. The principal product is wine. France, Italy and Spain are the leading producers of wine.

Sufficient quantity of production is also utilised in other ways such as table grapes, raisins, juice and canning. In India, the majority of fruits are used for table purpose. So grapes are divided into five main classes depending on their purpose. There are specific varieties for each purpose and certain varieties qualify for more than one purpose also.

1. *Table grapes* : The grapes which are utilised either as a fresh fruit or for decorative purpose are designated as table grapes. They must have an attractive appearance, good eating quality, good shipping and storage qualities and should be resistant to injury during handling. Appearance is the most important single factor for the sale of table grapes as it is rightly said "eye and not the mouth holds the key to stomach". Large berries of uniform size, with firm pulp, tough skin, a sturdy rachis and stronger berry attachment are most suited for the purpose. The clusters should be well filled (neither very compact nor loose). In India, there is a strong preference for elongated, seedless and white grapes. The varieties that are grown as table grapes in a given region are determined by climate and distances to preferred markets. The principal table varieties which can be grown successfully under North Indian conditions are Beauty Seedless, Perlette, Pusa Seedless, Delight, Thompson Seedless, Cardinal and Gold. Anab-e-Shahi is the mainstay of grape cultivation in Hyderabad (Andhra Pradesh). Bangalore Blue, Cheema Sahebi, Kali Sahebi, Gulabi, Pandhari Sahebi, Bangalore Purple, Bhokri and Black Champa are grown in other grape growing regions of India. Elongated berried grapes from Tasgaan area (Sangli) in Maharashtra are being sold under the varietal name Tas-e-Ganesh which appears to be a selection from Thompson Seedless and responds well to gibberellic acid treatment.

2. *Raisin Grapes* : The grapes that produce an acceptable dried product are included in this category. The market demands for large and nonsticky raisins. Bakers prefer very small sized raisins which can be distributed evenly in the product. Table grapes with high sugar content are ideally suited for raisins. Only a few varieties containing seeds are used for raisin and the product is called 'Manakka' in India, while dried seedless grapes are known as 'Kishmish'. The seeded varieties for raisins should have few, soft and tasteless seeds. For the production of suitable raisins several standards must be followed. These must be soft in texture and should not stick together. Yellowish with greenish tinge raisins are preferred in our country.

Apart from seedlessness, the raisin varieties should have good flavour and the berries should dry rapidly. In our country, a very small amount of grapes is

utilised for the purpose. Few varieties can meet all the criteria for raisin making. Some of the best are Thompson Seedless, Pusa Seedless and Kishmish Beli which are grown in our country. Black Corinth and Muscat of Alexandria also form good raisins.

3. *Juice grapes* : The juice of some varieties of grapes produces an acceptable unfermented beverage when it is preserved by pasteurisation, germ-proof filtration or other means. The clarifying and preserving procedure should not destroy the natural flavour. The strong muscat flavoured varieties which retain their flavour are preferred for sweet juice preparation. Beauty Seedless, Early Muscat, Champion, Black Champa and Bangalore Blue are suitable for juice making in India. Juice is generally prepared from Concord in the USA ; white Riesling and Chasselas in Central Europe ; and Aramon and Carignane in France.

4. *Wine-grapes* : As stated earlier, the principal product of grapes is wine. The produce of most of the vineyards in Europe, North Africa, South Africa, South America, Australia and the USA is wines. The varieties which can produce satisfactory wine in certain locality are termed as wine-grapes. Grapes of high acidity and low sugar are suitable for dry or table wines, while sweet or dessert wines are prepared from grapes with high sugar content, moderately low acid. The grape should retain flavor and colour in the wine. Grapes such as White Riesling, Pinot Noir, Char Donnay, Carignane, Cabernet Sauvignon, Tinta Madeira and Muscat Canelli produce good quality wine. In India, wine is produced at a very limited scale from grapes. However, the varieties like Beauty Seedless, Early Muscat and other table or juice grapes were tried for wine preparation in Haryana Agricultural University, Hissar. At present, the wine is being prepared from Beauty Seedless in Haryana. Investigations at the Indian Institute of Horticultural Research, Bangalore, revealed that for making dry white table wines, the varieties Bayan Sheree, Chenin Blanc, Sauvignon and White Riesling are suitable. Good quality red table wine can be prepared from Black Champa, Cabernet Sauvignon, Gamay and Zinfandel. Dessert type wines can be prepared from Convent Large Black and Black Muscat.

5. *Canning grapes* : A very small quantity of grapes is canned. Only seedless varieties like Thompson Seedless are canned alone or in combination with other fruits. Seedless white grapes with larger berries are preferred for canning or bottling. 20-24° Brix sugar syrup is generally used as canning medium.

Apart from the above discussed five ways of fruit utilisation, the grapes are also used for the preparation of grape syrup, jam and vinegar.

Grape is a commercial source of tartaric acid. Its juice acts as a stimulant to kidneys.

There are a number of winery bi-products such as :

(a) Tartrates (cream of tartar)

(b) Argols (wine stones). These settle on walls and base of wine tanks. These are purified as Rochelle salt.

(c) The oils from seeds are used as salad oils and in cosmetic industries.

(d) Pomace is used as cattle feed.

(e) Tannins can also be purified.

8.2 Origin and Distribution

In the area of the earliest human civilisation in a region somewhere between the Black and Caspian seas, the grape still grows wild. This region is considered by plant taxonomist to be the original home of the old world grape, *Vitis vinifera* L. (Snyder, 1937). Domestication started when migratory nomads marked forest trees that supported fruitful vines more often near watering holes serving their herds. Evolution of *Vitis* and *Muscadinia* is clearly depicted in Figure 1. It has been carried from region to region by civilised man in all temperate climates and more recently in tropical and subtropical climates.

Grape culture first began in Asia Minor. From there, it spread both west and east. Olmo (1976) has very clearly indicated the route of spread of *vinifera* grapes from its origin. Cultivation of wine grape was under way in the Near East as early as the fourth millennium B.C. There is no evidence of its cultivation on west of Greece until the first millennium B.C. The westward movement carried out from Asia Minor and Greece, following the Phoenician Sea routes. The vine followed the main river valley, the Danube, Rhone, Rhine, Tiber and Douro, and by A.D. 55, the northern most vineyards were established along the Moselle valley in Germany. The *vinifera* grape was introduced to the New World at the time of discovery and later accompanied practically all the Spanish and Portuguese voyages of discovery and conquest. The recorded evidences show its introduction to the east coast of the United States in 1621 by the London Company which was probably preceded by the Spanish landings in Florida. Recently, it is being introduced in tropical countries. In 1958, *vinifera* was introduced into the Phillipines from California (USA).

According to Olmo (1976) grapes might have been introduced in tropical India somewhere in 620 B.C. Grape is mentioned in Indian medical treatises written in the 1st century A.D. Evidences show that invadors from Afghanistan and Persia introduced grapes into India in A.D. 1300. Then it spread to all the grape growing areas of India such as Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. Commercial cultivation of grapes started only a few decade ago under North Indian conditions.

EVOLUTION OF THE GRAPES

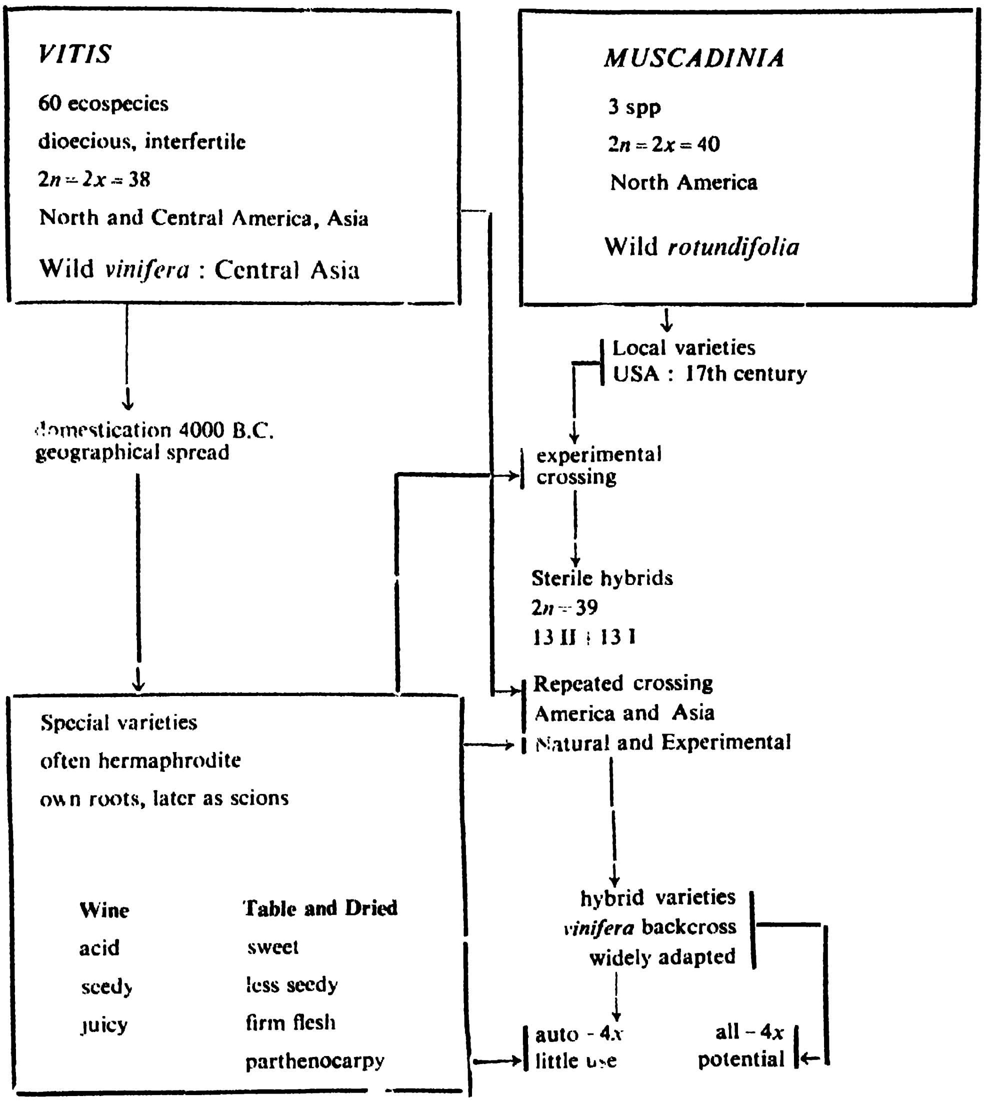


Fig. 1

(Dr. H. P. Olmo (1976) : from Evolution of Crop Plants, *ed*, N. W. Simmonds.)

8.3 Species and Varieties

Species

The grape belongs to the family *Vitaceae* which is made up of 12 genera and about 600 species widely distributed in the tropics and subtropics with ranges extending into the temperate regions. The genus of greatest economic importance and the only one containing food plants is *Vitis*. Some other important genera are *Ampelcissus*, *Cayratia*, *Cissus*, *Tetrastigma*, *Leea* and *Parthenocissus*.

The genus *Vitis* is subdivided into two subgenera, *Muscadinia* Plach ; and *Euvitis* Plach. The members of *Muscadinia* have 40 somatic chromosomes, while that of *Euvitis*, 38. *Muscadinia* can be easily identified by tight bark that does not shed, simple tendrils (that do not fork), nodes without a diaphragm (continuous pitch at nodes), and small clusters with berries that detach as they mature. *Vinifera* has forked tendrils, bark that sheds, a diaphragm at the nodes, and elongated clusters with berries that adhere to the pedicels at maturity. It also has intermittent tendrils, thin, smooth, shiny leaves with 3, 5 or 7 lobes ; round or oval berries with edible skins that adhere to the flesh. However, in American species the skins slip from the pulp and berries are always round or nearly round, with foxy odour in most of the species.

In *vinifera*, the 38 very small somatic chromosomes regularly form 19 bivalents at meiosis. The *Muscadinia* species (*M. rotundifolia*, *M. munsoniana* and *M. popenoei*) do not hybridise with the species of *Euvitis*. However, the possibility has been explored to improve the fruit quality of *rotundifolia* and disease resistance of *vinifera* by hybridising them experimentally. The cyto-genetics of the F_1 (*vinifera* × *rotundifolia*) with 39 somatic chromosomes and its backcross derivatives have been studied in some detail (Patel and Olmo, 1955). Such hybrids are highly or completely sterile with occasional viable seeds. At meiosis 13 bivalents are formed with 13 univalents showing that 13 chromosomes of *vinifera* and *rotundifolia* are homologous enough to pair. The ancient basic chromosome number in the family are probably 5, 6 and 7. Vitis species thus appear to be ancient secondary polyploids involving 3 basic sets in the combination $(6+7)+6=19$ and *Muscadinia* are $(6+7)+7=20$. These have undergone diploidisation to give regular bivalent pairing.

The genus *Vitis* contains about 60 species with only 3 species in the *Muscadinia*. While studying the origin and world distribution of *Vitis*, De Lattin (1939) grouped many species of *Euvitis* into the following nine sections.

1. Labruscae	4. Muscadinia	7. Incertae
2. Cinerascentes	5. Aestivales	8. Viniferae
3. Ripariae	6. Rupestres	9. Labruscoideas

He included 18 North American species in the groups, while Bailey (1934) included 28 American species and his groupings and their designations varied. Lavadoux

et al, (1962) placed them in a single co-species with 38 somatic chromosomes. This confusion arises because the systematic botanists and ampelographers differ as to what constitutes good species, extreme variants and hybrid forms (Barrett *et al*, 1969). The various species of *Vitis* and *Muscadinia* are shown in Table 5.

TABLE 5. SOME SPECIES OF *VITIS* AND *MUSCADINIA* FOUND IN VARIOUS REGIONS OF THE WORLD (Prepared by H P. Olmo)

I. Middle Asian and Mediterranean

V. vinifera, Linnaeus. Wine grape

II. North American

V. aestivalis, Michaux. 'Summer Grape'
V. argentifolia, Munson. 'Silverleaf Grape'
V. arizonica, Englemann. 'Canyon Grape'
V. berlandieri, Planchon. 'Spanish Grape'
V. baileyana, Munson. 'Possum Grape'
V. californica, Bentham. 'Pacific Grape'
V. candicans, Englemann. 'Mustang Grape'
V. champini, Planchon. 'Calcaric Grape'
V. cinerea, Englemann. 'Grayback Grape'
V. cordifolia, Lamarck. 'Winter Grape'
V. gigas, Fennell. 'Florida Blue Grape'
V. helleri, Small. 'Round-leaf Grape'
V. illex, Bailey. 'Manatee Grape'
V. labrusca, Linnaeus. 'Fox Grape'
V. lincecumii, Buckley. 'Post-oak Grape'
V. longii. Prince (solonis and novo-Mexicana). 'Bush Grape'
V. monticola, Buckley. 'Sweet Mountain Grape'
V. novae-angliae, Fernald. 'Pilgrim Grape'
V. palmata (rubra), Vahl. 'Cat Grape'
V. riparia, Michaux. (*V. vulpina*. Linn.) 'Frost Grape'
V. rufotomentosa, Small. 'Redshank Grape'
V. rupestris, Scheele. 'Sand Grape'
V. shuttleworthii, House. 'Calloosa Grape'
V. smalliana, Bailey. 'Fig-leaf Grape'
V. simpsoni, Munson. 'Current Grape'
V. sola, Bailey. 'Curtiss Grape'
V. treleasei, Munson. 'Gulch Grape'

III. Carribean

V. indica (tiliafolia, caribeaca)

IV. Asiatic species

V. coignetiae, Pulliat.
V. flexuosa, Thunberg.
V. pentagona, Diels and Gilg.
V. amurensis, Ruprecht.
V. embergeri, Golet.
V. betulifolia, Diels and Gilg.
V. reticulata, Pampanini.
V. armata, Diels and Gilg.
V. davidii, Romanet du Caillaud.
V. lanata, Roxburgh.
V. pedicellata, Lawson.

V. Genus Muscadinia (the Muscadine grapes)

M. rotundifolia Michaux. 'Muscadine Grape'
M. munsoniana Simpson. 'Little Muscadine Grape'.
M. popenoei Fennel. 'Mexican Muscadine Grape'.

Vitis vinifera produces over 90 per cent of the world's grapes which are either pure *vinifera* or *vinifera* hybrids. Hybrids gave many varieties by cross-breeding between native species, between a species and a hybrid previously produced or by crossing two hybrids (Winkler *et al.* 1974). The most important species are *V. labrusca*, *V. aestivalis*, *V. vulpina*, *M. rotundifolia* and *V. rupestris*.

Some of these species (Table 5) are important as rootstocks. These are *riparia*, *berlandieri*, *rupestris*, *aestivalis*, *cordifolia*, *monticola*, *rotundifolia*, *champini*, *candicans* and *longi*.

Varieties

There are about 10,000 varieties in the world that have been named and described. However, no exact estimate can be given for grape varietal situation of the world, as there are a number of synonyms for the same variety in different regions. Vial and Vermorel (1901-10) were the first to give about 24,000 names of synonyms representing about 5,200 varieties. Badell (1952) and Levadoux (1952) have also made significant contribution to the study of synonyms. The description of vine varieties had been taken up by several workers since 250 B.C. Chadha and Randhawa (1974) have given a detailed account of the work done on this aspect in early times and in the 20th century by ampelographers of different grape growing countries.

In India, introduction of grape variety started as early as 1838 (Watt, 1893). Punjab was perhaps the first to take up comprehensive introduction and trials for testing the adaptability of varieties. As a result of these efforts, over 1000 varieties now exist in the collection of Experimental Stations in the country.

So far, not much has been reported on grape variety descriptions and their important characters from our country. The only standard one in this direction was published by Singh and Singh (1940). The most systematic work on 108 grape varieties grown at the Indian Agricultural Research Institute (IARI), New Delhi was carried out by Chadha (1965). Mustafa (1967) described another 20 varieties not earlier described by Chadha (1965). Since then, many workers have given brief description of a few varieties of local importance. Chadha and Randhawa (1974) have given a detailed description and classification of 130 varieties in India.

The number of varieties being maintained at Experimental Stations may be quite large in India, which are a potential tool to a grape breeder. However, only a few of these varieties are important so far as commercial cultivation is concerned. Most of the varieties recommended for commercial cultivation in different grape growing regions in India were introduced from the USA and the USSR. Apart from these introductions, some varieties were also released for cultivation which arose as a result of selections, seedling selection and hybridisation as well.

Some important characters of commercial varieties grown in India are given below :

Seeded varieties

Anab-e-Shahi : It was introduced in Hyderabad by Abdul Baquer from the Middle East around 1890. It is considered synonymous to 'Malta'. It has been acclaimed as one of the most productive varieties grown in India. It is a principal variety of Andhra Pradesh and also grown in Maharashtra, Karnataka, Gujarat. In North India, its performance is not satisfactory. It has wide range of adaptability to soil and climatic conditions.

The vine is vigorous and gives very high yield on bower system of training. It has attractive large bunches and berries with good shipping quality. Quality is average in North, and good in South and West India. Ripening is uniform and late. In humid regions and in case of early monsoons at the ripening, the berries become watery and insipid.

Bangalore Blue : Its cultivation is mainly confined to the surroundings of Bangalore in Karnataka. The thick, separable berry skin indicates *labrusca* blood in it. Chatterjee and Randhawa (1952) reported it to be a *vinifera* × *labrusca* hybrid. It does not ripen in North India. It responds well to staggering of pruning and can produce two crops in a year around Bangalore.

It is medium in vigour and yield. It does well on Kniffin as well as bower systems of training. The bunches are small and compact. The berries are small to medium and dark blackish-purple in colour. The ripening is uniform. Apart from being used for table purpose, it is being extensively used for juice and wine in Karnataka. It is known for its hardiness and resistance to disease for which

it finds a suitable place as parent in a breeding programme aimed at inducing disease resistance.

Bangalore Purple : This variety is considered to be synonymous with Bangalore Blue (Gandhi, 1960 ; Phandis, 1965). However, the two varieties are entirely different. It is grown in Karnataka. It does not perform well in North India as ripening is late and it is prone to cracking and rotting because of onset of rains.

The vines are medium in vigour and yield. The bunches are medium large, shot berries are commonly found. The berries are bluish-black in colour and spherical in shape. Quality is fair. It is a juicy and uneven ripening variety.

Banqui Abyad : It is an excellent table variety having large-sized bunch and berry. It is green, seeded, early and very sweet variety. Its flowers are reflexed-stamen type ; therefore, it should be planted along with other varieties.

The vines are low to medium in vigour. The bunches are often shouldered and compact. The berries are greenish-yellow and spherical. The pulp is firm, juicy and it has musky flavour. Sometimes, it cracks under high humid conditions.

Bharat Early : This is a green, seeded, mid-season variety with high total soluble solids (TSS) and muscat flavour. It does well in North India and ripens by the middle of June. Rotting starts if the bunches are allowed to remain in vines for long.

The vines are medium in vigour. It gives yield better on bower than Kniffin system of training. It is a light to medium cropper. The bunches are small to medium with small and spherical to oblate berries. The ripening is uniform.

Bhokri : It was introduced in Deccan in 1838 under the name 'Bokhari' and is one of the oldest varieties in cultivation. Later on, it was known as 'Bhokri'. It is also known as 'Nasik' and 'Pacha Drakshi'. Prior to 1950, it occupied nearly 99 per cent of total grape area in Maharashtra, Tamil Nadu and Andhra Pradesh. However, now it has been replaced by Anab-e-Shahi and Thompson Seedless.

The vines are very vigorous with very high yielding capacity. It is a prolific bearer on bower system, however, it does well on trellis and other systems of training also. The bunches are large, compact and usually shouldered. The berries are green and oval with soft pulp. Ripening is late and uniform. Berries crack with rain and its keeping quality is poor.

Bian Shirai : It is an introduction from USSR. It ripens in the third week of June under North Indian conditions. The bunches are large and loose with greenish-white, medium-sized spherical berries. This variety does well on trellis as well as bower systems of training as vines are vigorous.

Black Champa : It was selected from the introductions at the Indian Institute of Horticultural Research (IIHR), Bangalore, which is being used in the breeding

programmes of this Institute. The vines are vigorous with medium yielding capacity. It is a purple, seeded grape of excellent quality. It is suitable for table, juice and red dessert wine. Bunches are small, well-filled with small to medium berries. It is susceptible to cracking and rotting during rains.

Cardinal : This variety was evolved as a result of cross between Tokay × Ribier made by E. Snyder of California (USA). It is a very early, red, seeded table grape. It has done well in the arid irrigated regions of North India. The vine is medium in vigor. Clusters are attractive, medium to large, loose and conical with large, bright red and spherical berries. The colour changes to reddish black as ripening proceeds. It has a great promise in hot irrigated areas of North India. Sometime highly variable size of berries are found within a bunch.

Champion : An excellent variety with highly flavoured juice. The bunches are small and conical with medium-sized spherical berries. Under Haryana conditions, ripening starts by the middle of June. This variety is juicy with TSS 21 per cent and has a promise for juice industry.

Cheema Sahebi : This variety was selected by Dr. G. S. Cheema from the open pollinated seedlings of 'Pandhari Sahebi'. Earlier, it was known as 'Selection 7'. It is grown mainly in Maharashtra. It has been tried in North India where it has not performed well due to its late ripening which coincides with the onset of rains.

The vine is vigorous and a very heavy yielder. Bunches are long, conical and shouldered with medium-sized, oval and pale berries. In North India, its quality is poor. However, in Poona area, the fruit quality is better than Bhokri and Anab-e-Shahi. Shipping quality is poor due to weak pedicellar attachment. It is a late-ripening variety.

Early muscat : This variety was introduced from California (USA). It starts ripening early (end of May) under North Indian condition. The ripening is uneven. Its juice is highly flavoured and has a promise for juice industry.

The vine is medium in vigour which does well on Kniffin system of training. It is a green, seeded grape of good quality with pronounced muscat flavour. The bunches are loose to well-filled with yellowish-green berries which turn golden green when over-ripe.

Gold : It has done well in the arid irrigated tracts of Punjab and Haryana. It is an early mid-season grape with large oval berries. The berries are golden coloured and have a mild muscat flavour. The bunches are loose and medium in size.

The vine is medium in vigour and yields heavy on bower system of training. It ripens by the first week of June in Haryana. It is a table variety with good eating and keeping quality. Panicle drying has been reported to be a serious obstacle in extending area with this variety in Haryana (Jindal and Sharma, 1982).

Gulabi : It is also known as Karachi, Paneer Drakshi and Muscat. Its performance under North Indian condition is satisfactory. It is mostly grown in Tamil Nadu. According to Gandhi (1960) it resembles Muscat Hamburg of Australia. The vine is medium in vigour and yield ; bunches are small and loose with deep purple, small and spherical berries. It has thick-skinned berries which attribute to good keeping quality. It has a muscat flavour. The ripening is early and fairly uniform.

Kali Sahebi : This variety is believed to be introduced sometime in the 17th century under the name Habshi which came to be known as Kali Sahebi in Poona and Nasik areas. It is grown in Maharashtra and Andhra Pradesh and ripens late in North India and quality remains poor.

The vine is vigorous with moderate yield. The bunch is very attractive, well-filled and medium-sized. The berries are large, black and elongated. It fetches good price in market due to its attractive bunches, thin skin and sweet pulp. It has good keeping quality.

Pandhari Sahebi : The variety was introduced in Deccan under the name Sahebi which when brought to Nasik and Poona area was known as Pandhari Sahebi. It is one of the best table varieties of Deccan but could not gain popularity because of poor yield.

Pearl-of-Casaba : It is the earliest ripening variety so far known in North India which starts ripening by the third week of May. It is being used in hybridisation programme at IARI, New Delhi, to develop early ripening seedless good quality variety. The vines are poor in vigour. The bunches are small and well-filled with light green, spherical berries. It has slight muscat flavour and pulp is tender and very sweet. Due to its low yield and small bunches with high seed content, it may not be suitable as a commercial variety but it is a valuable parent for hybridisation programme.

Seedless varieties

Beauty Seedless : It is an introduction from California (USA) and was released for cultivation from Indian Agricultural Research Institute, New Delhi. It is a very early ripening variety which starts ripening at the end of May in Punjab, Haryana, Delhi and other North Indian grape growing tracts before the onset of monsoon. Berries shrivel if kept on vine for long. It is prolific bearer with low keeping quality. Therefore, the cultivation is limited to only near the big markets. It has great future in processing industry for juice making.

The vine is medium in vigour. The bunches are medium to large, long, shouldered and compact with bluish-black, spherical, medium-sized berries. Heavy pre-harvest berry drop is the main hindrance in extending the area under this variety in Haryana (Chundawat and Jindal, 1979). Fruiting is basal and responds well to spur pruning. It can be easily trained on head system of training at a very

low establishment cost. The vine is very hardy and moderately susceptible to diseases.

Delight : This variety is a sister seedling of 'Perlette' evolved by Dr H. P. Olmo at the University of California, USA. It is a hybrid of the cross between 'Scolokertekhiralynoje 26 (Hungarian) × Sultanina Marble (Russian) made in 1936. This variety was marked for its very early ripening habit and characteristic muscat like flavour. The variety has performed well in Punjab and Haryana and has been recommended for commercial cultivation.

It is less vigorous and can be trained on head system of training. It starts ripening by the first week of June. The bunch is medium in size, compact, conical and attractive with green, small and almost round berries. It has good eating and shipping quality.

Himrod : This variety originated as a cross between Ontario (American type) × Sultanina (Thompson Seedless) made in 1928. This is a recent introduction to India. It has given good performance in Punjab, Haryana and Uttar Pradesh. It is a prolific bearer, excellent in quality and mid-season variety which is resistant to diseases and pests. The skin is thick and tough which is slight difficult to chew.

Vine is vigorous and heavy yielder. Bunches are attractive, medium large, shouldered and well filled with yellow green berries. It has been recommended for commercial cultivation in Punjab.

Kishmish Beli : It is an introduction from the USSR, where it is a commercial raisin variety. It has done well in the North at Delhi, Abohar and Hissar.

The vines are medium in vigour and yield. It has well-sized, well-filled and cylindrical bunches with light golden coloured, small-sized, slightly elongated berries. It ripens by the middle of June in North India and quality is good for table as well as raisin purposes.

Kishmish Charni : It is an introduction from the USSR, where it is a valued seedless variety of Uzbekistan and next to Kishmish Beli in area there. It has done well in irrigated arid tracts of Punjab, Haryana and Delhi. It is a mid-season variety.

The vines are medium in vigour. The bunch is medium to large, conical, shouldered and well-filled to compact. The berries are brick red, spherical medium large and slightly elongated. It is a very sweet variety with high keeping quality. Yields are low to medium. It gives good yield on bower system of training and responds to longer cane pruning.

Perlette : This variety is a hybrid of Scolokertekhiralynoje 26 × Sultanina Marble developed at the University of California, Davis, by Dr H. P. Olmo. The most striking feature is the transluscence of the mature fruit. The French name 'Perlette' signifying 'little pearl' clearly explains this striking feature. It is the most popular variety of North and Western India. It is one of the earliest

maturing variety which has performed well in all the grape growing tracts of North India. It is a prolific bearer and yields about twice as much as the Thompson Seedless.

The vine is vigorous and can be trained on head as well as bower systems of training. Highest yields are obtained on bower system. The bunches are medium-large, conical, shouldered and very compact. The major defect is too compact a bunch and it needs berry thinning. Berries are medium in size, whitish green and spherical. Flesh is soft and mild muscat flavoured. It has good keeping quality. Small underdeveloped berries (shot berries) scattered all over the bunch is another major defect. The bunch compactness is reduced in a new strain 'Loose Perlette' which was the result of irradiation. Likewise, an early ripening clone has also been reported from Haryana (Singh *et al*, 1974).

Pusa Seedless : It is a selection made at the Indian Agricultural Research Institute, New Delhi, from unknown origin. However, it resembles Thompson Seedless in many characters. It has performed well in North India. It is different from well-known Thompson Seedless only by the shape of the berry which is slightly more elongated. It is next to Perlette in its popularity in North India. Being a good quality grape, it fetches more price than Perlette in the market.

Vine is vigorous and medium yielder. It ripens uniformly in the 2nd to 3rd week of June at Delhi. Apart from table purpose, good quality raisin can also be prepared from it. It has good keeping quality.

Thompson Seedless : It originated in Asia Minor and was first grown by William Thompson. It is also called 'Oval Kishmish' in the eastern Mediterranean region and Sultanina in Australia and South Africa (Winkler, 1965). It is a table and a raisin variety as well. More than half of the total world raisins are prepared from this variety alone. Large quantities of white dessert wines are also made from this variety. It has wide adaptability and has performed well in all the grape growing regions of the country. Its yields are lower than Anab-e-Shahi but it surpasses Anab-e-Shahi in quality and commands premium in the market. It is mid-season and uniform in ripening.

Vine is medium in vigour and responds well to longer cane pruning and bower system of training. The bunch is medium-large, long, conical to cylindrical, shouldered and compact. The berries are yellowish green to golden yellow when fully ripe, small and elongated. Eating and keeping qualities are excellent. It ripens in the middle of June in the North and during February-April in Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka.

It has certainly created a place of its own in Maharashtra, especially in Sangli area, where most other varieties are being replaced by Thompson Seedless. Farmers have also made their own selections and some of these have been named. At Borgaon in Sangli district of Maharashtra, Mr. Arve, a grower has selected a clone from Thompson Seedless, which is more responsive to gibberellic acid

treatment and named as Tas-A-Ganesh (Anon., 1981). In all other characters it resembles Thompson Seedless.

Apart from these, certain other varieties like Black Prince, Black Muscat, Black Hamburg, Khalili, Seedless White Round, Kandhari, Hur, Fakdi, etc., are also important and have some area under cultivation. In order to evolve varieties for local adaptability, grape breeding work is in progress at IARI, New Delhi, IIHR, Bangalore and a few state universities and departments. At IARI, some promising hybrids have been selected and being multiplied for large scale trials which may find a suitable place in grape industry of at least North India. Recently, 4 hybrids have been named and released from IIHR, Bangalore (Negi and Randhawa, 1980), which are Arkavati, Arka Hans, Arka Shyam and Arka Kanchan.

8.4 Soil and Climate

The important factors governing the successful vine growing are soil and climate. Grape vine has powerful root system and it is found growing on a wide variety of soils with varying degree of success. However, the climate is of major importance in limiting the commercial grape growing. Among different climatic factors, special significance is attached to temperature and distribution of the rainfall.

Soil

Grapes can be grown on a variety of soil ranging from gravelly sands to clay loams and shallow to very deep. The best suited soils are sandy loams that are well drained and fairly fertile with good amount of organic matter. Heavy clays, wet and low lying soils should be avoided. The grape is moderately tolerant to salinity and alkalinity but excessive lime is harmful. The soils containing salt concentrations of 0·30 per cent or more should not be selected for grape cultivation (Pandey and Divte, 1976). Likewise, exchangeable sodium percentage (ESP) of 45 and more are injurious to grapes (Khanduja *et al*, 1980). The variety Anab-e-Shahi has been reported to be more susceptible to salinity than Bangalore Purple and Cheema Sahebi (Gupta and Naurayal. 1973). Likewise, Dharmparkash (1969) found Perlette and Khalili as most susceptible ; Himrod, moderately tolerant and Alamwick, Thompson Seedless and Beauty Seedless comparatively resistant to salinity.

Climate

The *vinifera* grapes require long, warm to hot, dry summers and cool winters. Under humid summer conditions, vines do not grow well as they are susceptible to disease under such conditions. Grape can tolerate high humidity better in cool

regions than warmer regions. Bright sunny days help in the development of sugar in the berries. However, in very high temperatures, the berry skin becomes thicker. The total amount of heat received (degree days) determines the ripening time. The total heat received can be expressed in terms of temperature time value called 'degree days' or heat units. The heat units are calculated by multiplying the mean daily temperature over and above 10°C and the number of days. Generally, the calculations are made right from full bloom. Certain specific heat-units are required for ripening of a particular variety. The early and the late ones require 1600 and 3500 degree days for ripening respectively (Jacob, 1950).

The distribution of rain, rather than the total amount of rainfall is most important. Rainfall during the growing season is desirable, however, under continuous rains, it is difficult to control disease. Rains or cloudy weather during bloom results in poor berry set. Rains at ripening may cause considerable damage to crops through berry splitting and rotting. Hot and dry season is essential at ripening and adds to the quality of fruits. The vine can tolerate low temperature or frost with little damage in the dormant period. Low temperature in winter helps in leaf fall and the vines enter dormant period. Frost that occurs in spring causes damage to sprouting buds. Hails during fruiting season may cause considerable damage to the vine.

In India, grapes are grown in semi-arid irrigated regions of North India and central, southern and costal tropical regions as well. The vines remain dormant during winter under North India. Under tropical climate, the vines do not enter dormancy and make luxuriant growth.

8.5 Area and Production

The world's production of grapes exceeds that of any other fruit crop. Roughly, the vineyards of the world occupy 11 M ha.

The grapes are grown widely throughout the world wherever the climate is favourable. These are grown in temperate as well as tropical countries. The total area under grapes in the important countries of different continents, viz., North America, Australia, Africa, Europe and Asia is shown in Table 3.

Apart from the countries listed in the Table, grapes are grown over an area cf 294,100 acres in Chile ; 23,800 acres in Peru ; 46,000 acres in Uruguay and 22,500 acres in Israel (Winkler *et al*, 1974).

Grapes are grown under tropical as well as subtropical climate in India. The tropical states, namely, Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu jointly contribute to more than 90 per cent of the total area and production of grapes in India. During the last two decades, grape cultivation has gained a considerable momentum in the States of Haryana, Punjab, Rajasthan, Delhi and western Uttar Pradesh. Area under grapes is steadily increasing in India and

TABLE 3. AREA AND PRODUCTION OF GRAPE IN DIFFERENT COUNTRIES OF THE WORLD IN 1973*

Country	Area (acres)
Spain	4,124,900
Italy	3,381,430
France	3,255,460
USSR	2,677,480
Turkey	2,025,400
Portugal	879,320
Romania	827,450
Argentina	770,640 (1972 data)
Algeria	615,030
Yogoslavia	615,030
California (USA)	607,620
Hungary	526,110
Greece	506,350
Bulgaria	494,000
South Africa	350,740 (1972 data)
Afghanistan	269,230
Iran	247,000
Germany (West)	237,120
Brazil	180,310
Morocco	172,900
Syria	167,960 (1972 data)
Australia	167,960 (1972 data)
Austria	116,090
Cyprus	121,030 (1972 data)
Czechoslovakia	93,860
Tunisia	91,390
Mexico	81,510
Japan	54,340
Lebanan	41,990
Egypt (UAR)	37,050
Albania	32,110
Switzerland	32,110
Canada	22,230
Bolivia	14,820 (1971 data)
Jordon	14,820+
India	93,860
Libya	7,410+
Pakistan	4,940 (1971 data)
Paraguay	4,940 (1971 data)
Luxembourg	2,470
Thailand	2,964 (1971 data)
New Zealand	2,470
Malta	2,470 (1971 data)
Belgium	864·5 (1971 data)
Colombia	741 (1971 data)
World total (approximate)	24,011,080

*Bulletin de International de la Vigne et du Vin, 47 (525) : 916-950 (1974). Reproduced from Weaver (1976)

+ Estimate.

there is a great scope of extending the grape growing to some parts of Gujarat, Madhya Pradesh and Orissa also. The latest available statewise area and production of grapes in India is shown in Table 4.

8.6 Propagation

There are two main methods of propagating grapevines. One is sexual which involves multiplication by seed. The sexual method is employed chiefly for evolving new varieties through hybridisation. The second type is asexual or vegetative where the vines are multiplied by means of vegetative parts such as branches, buds, canes, etc. Among the different asexual methods, the most common method of propagation in grape is by hardwood cutting. The vines are also propagated by other means such as budding, grafting, layering and tissue culture.

Seed

Freshly harvested seeds of grapes have poor germination and they are stratified for higher percentage and uniform germination. Exposure to lower temperature between 0 and 10°C for 5 months was found effective in breaking the dormancy (Balhazard, 1974). When the seeds were kept in a peat, sand (1 : 1) mixture plus 0·3 per cent Captan in polythene bag at 0-2°C showed 79·6 per cent germination at 27°C (Misic *et al*, 1978). After-ripened seeds treated with GA_3 was found to promote germination, especially at lower concentrations, i.e., 100, 250 or 500 ppm (Pal *et al*, 1976.)

Vegetative propagation

Cuttings

A cutting is a piece of a parent plant (stem, root or leaf) that will develop into a new plant when placed under conditions favourable for rooting. Cuttings are always made from mature canes of healthy, moderately, vigorous and virus free vines. The cuttings are prepared at the time of pruning in January in North India and preferably from October pruning in South India. Depending upon the length of internodes in a variety, mature wood is cut into pieces about 23-46 cm long and it should have at least four buds. However, two node cuttings and single bud cuttings taken before and after bud burst have also been reported to be successful (Csepregi, 1960; Colo and Liuni, 1964-65). In sandy soils, longer cuttings are preferred so that their bases will be in moist soil. The cutting should be of pencil thickness (7-8 mm dia.). The cut at the base of the cutting is made perpendicular to the cuttings length just below the bud, while the upper cut should be slanting and about 1·5 cm above the apical bud. This avoids injury to the apical bud and facilitates orientation of the cuttings in planting. They should be planted

TABLE 4: STATEWISE AREA AND PRODUCTION OF GRAPES IN INDIA**

A (area) = 000 ha

P (production) = 000 tonnes

State	1976-77		1977-78		1978-79		1979-80		1980-81		1981-82		1982-83	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P
Andhra Pradesh	0·84	19·10	0·84	19·10	0·77	19·10*	0·84	19·10	0·84	19·10	0·84	19·10	0·84	19·10
Haryana	0·37	1·12	0·37	1·12	0·39	1·74	0·42	1·89	0·44	1·33	0·47	1·42	0·47*	1·42
Kerala	0·95	3·32	0·95*	3·32	0·95	3·32	0·95	3·32	0·95	3·32	0·95	3·32	0·95	3·32
Karnataka	4·65	91·23	4·26	106·60	4·86	121·60	5·38	134·60	5·86	146·60	6·42	160·60	6·98	174·60
Maharashtra	2·10	31·50	2·10*	31·50	2·10	31·50	2·10	31·50	2·10	31·50	2·10	31·50	2·10	31·50
Punjab	0·44	4·38	0·44	4·36	0·49	4·90	0·54	5·44	0·64	5·99	0·65	6·53	0·71	7·08
Total	9·35	150·65	8·96	166·00	9·56	182·16	10·23	195·85	10·83	207·84	11·43	222·47	12·05	237·02

* Figures of previous year

** *Source*: Statewise Area and Production of Important Fruits in India from 1976-77 to 1978-79 and Projections up to 1982-83. Government of India, Ministry of Agriculture, (Department of Agriculture and Co-operation, Crops Division), New Delhi.

N.B. Projections for 1979-80 onward.

in the beds for rooting as soon as they are made. If they cannot be planted immediately, these can be burried in moist sand or saw dust in a cool place. To facilitate handling and storage, the cuttings are tied into bundles of 100 or more along with a proper label of the variety. Cuttings planted immediately after they are prepared, give as good results as those callused during storage (Singh and Singh, 1973). The treatment of cuttings with indole butyric acid (IBA) helped greatly in producing nursery plants with better root and shoot growth which facilitated establishment (Singh and Singh, 1973). Singh *et al*. (1971) found 500 ppm IBA as the appropriate concentration and higher concentrations proved injurious. Grape cuttings root easily and give good success (70-75 per cent) even without any treatment.

The cuttings are planted in flat beds in a slanting position leaving two nodes above the soil surface. The nursery soil should be fertile and preferably sandy loam. After planting, some of the cuttings sprout without initiating roots which later on dry. In order to solve this problem, the work conducted at IARI, New Delhi, with respect to initiating roots, by putting the grape cuttings in a bottom heat chamber when the atmospheric temperature is still not congenial for growth, is of tremendous importance (Majumder, 1983 personal communication). In this method, the cuttings are made to root without sprouting and instant grape plants can be prepared for planting direct in the field in the same season with good success in establishment (80 per cent). The development of mist propagation has enabled softwood cuttings of grape to be rooted with success (Smakov, 1939 ; Fahmy, 1963).

The cuttings are allowed to grow in the nursery for one season and can be lifted late in January any time after leaf fall under North Indian condition. Under tropical Indian conditions, the rooted cuttings will be ready for planting in field about 4 months after planting in the nursery.

Layering

This method is adopted to multiply vines of difficult-to-root variety and to replace occasional missing vines in an established vineyard. Sulikeri and Sulladmath (1980) gave a quick method of gap filling in grape vineyard by improvised technique of layering.

Budding and grafting

Grapevines are also propagated by budding (chip budding) and grafting (whip, cleft, side, notch, wedge, barb, green, high level and bench) under certain specific conditions as follows :

- (i) To establish vines on a rootstock resistant to soil-borne pests, diseases, nematodes or certain soil conditions (saline or alkali soils).
- (ii) To correct the mixed varieties or to replace varieties in a established vineyard without uprooting.
- (iii) To increase the supply of rare variety rapidly.

Alley (1979) described an improved method of chip budding and reported that many vines produced fruits in the very first year on the new head. He (1981) also reported that chip budding in April was found as successful at T-budding in June, but the take of chip budding in March was lower. Dass and Melanta (1973) in a study on whip and splice grafting, and chip budding operated during the months of April and October reported that chip budding gave better result than whip grafting. In October, splice grafting proved effective as compared to chip budding, for the varieties Gulabi and Cheema Sahebi. Steinhaner *et al*, (1980) in an experiment with four methods, viz., ground level wedge graft, high level wedge graft, chip and T-bud in Cabernet Sauvignon and Merlot vines observed that high graft gave significantly lower bud-take, while low wedge graft gave good results in one locality but poor in another. Chip and T-budding showed good results in two different places with bud-take ranging from 66 to 77 per cent.

Rootstock

Fortunately, phylloxera is not a problem in India. However, nematodes are posing some problems. Likewise, under arid-irrigated tracts of North India, high salinity poses a problem for vineyard establishment. Therefore, the use of rootstock becomes a necessity. Dass *et al*, (1981) compared 6 rootstocks to combat nematode problem in Anab-e-Shahi and found that yield on 1613 was higher than on any other rootstock or even Anab-e-Shahi on its own roots.

Some important phylloxera-resistant rootstocks are :

(i) Riparia Gloric (Syn. Gloric de Montpellier, Glorie) is a seedling selection from *Vitis riparia.*

(ii) St. George (Syn. Rupestris du Lot, Rupestris St. George) is a variety of *Vitis rupestris.*

(iii) A × R 1 (Syn. Ganzin No. 1 ; Aramon × Rupestris Ganzin No. 1 ; A × RG, No. 1, A × R) arose as a hybrid between the species *Vitis vinifera* variety Aramon and the phylloxera-resistant species *Vitis rupestris*, variety Ganzin.

(iv) 1202 (Syn. Couderc 1202 ; Mourvedre × Rupestris No. 1202) is a variety arising as a hybrid between the fruiting type Mataro (Mourvedre) and *Vitis rupestris.*

(v) 99-R (Syn. Richter 99 ; Berlandieri × Rupestris No. 99) is a variety arising as a hybrid between species *Vitis berlandieri* and *Vitis rupestris.*

The important nematode-resistant rootstocks are as follows :

(i) Dogridge—a variety of *V. champini.*

(ii) Salt Creek (Syn. Ramsey, *V. champini* Salt Creek).

(iii) 1613 (Syn. Courderc 1613 ; Solonis × Othello 1613 ; Solonis-Othello) is a variety arising as a hybrid between *V. solonis* and the fruiting variety Othello.

(iv) 1616 (*Solonis* × *riparia* 1616).
(v) Teleki 5-A (*Berlandieri* × *riparia* 5-A)

Propagation through tissue culture

Recently, some progress has been made for rapid multiplication of grapevine using tissue culture techniques. In future, tissue culture may replace the traditional methods of vegetative propagation in fruit crops and grape will not be an exception to it. Some success has been made with regard to *in vitro* propagation of grape vine using different parts such as leaf blades (Favre, 1977), axillary buds (Jona and Webb, 1978), and shoot apices (Barlass and Skene, 1978 and 1980). Callus cultures have also been utilised for the formation of somatic embryos and production of a large number of plantlets by Mullins and Srinivasan (1976) and Krul and Worley (1977).

8.7 Cultivation

Preparation of land and layout

While selecting a site for planting a vineyard, the factors like vicinity to the market, road, railway station, storage facility and preservations industry need special consideration. The fruit is perishable and cannot be stored or transported to long distances without cold storage or refrigerated vans. The soil should be analysed thoroughly and special significance should be attached to its salt content. The soil should be levelled to ensure smooth irrigation of the vineyard. The plot is thoroughly ploughed and manured. On soils, which are deficient in organic matter, green manure crop should be grown. However, fertile soil, need not be green manured.

A proper layout of a vineyard is pre-requisite as any mistake made initially may not be corrected afterwards and will be troublesome. In a properly laid out orchard, the cultural operations become easy and it is of great aesthetic value. For locating the plants, rows, pillars, channels, etc., it is advisable to prepare a sketch plan on a graph paper and afterwards develop it in the selected field. In plains, the square system is usually followed for planting which allows cultivation and irrigation in two directions. The spacing between the rows and the vines is governed by the vigour of the variety and the training system. The vigorous varieties are trained on bower system with longer spacings (3m × 3m). The varieties trained on head system may be set closer (2·0 × 2·0 m).

A base line is fixed parallel to a permanent feature such as road or building. A rectangle or a square is drawn on this line. In this way, the complete position of rows and plants is worked out. Before planting a vineyard, it is necessary to make provision of the wind breaks. Eucalyptus is the most economical wind break with a hedge of karonda (*Carissa carandas*) or mehendi (*Lawsonia alba*) in between the

trees. The wind break protects the vines from hot desiccating winds that blow over the plains of North India during May and June. The vine rows should preferably be in east-west direction.

Planting

The most common system of planting vineyards in the plains is square system. However, in less vigorous varieties and for mechanised cultivation, the spacing between the rows is increased and between the vines decreased, thus adopting rectangular system of planting. Pits (90 cm deep and 90 cm diameter) are dug according to layout plan. While digging the pits, the top half-depth soil is separately heaped. These are allowed to remain open for 2-3 weeks. The pits are filled back with 1 : 1 mixture of top soil and farm yard or organic manure. One kg of superphosphate (single) and 500 gm of sulphate of potash may preferably be added to it. In each pit 30 gm Aldrin 5 per cent or BHC 10 per cent is mixed thoroughly with the soil as protection against termites. The soil should be allowed to settle by an irrigation. Makhija (personal communication) found better establishment of vines under saline soil, when the pits (upper 30 cm) were filled with non-saline good soil separated with alkathene lining (300 gauge).

One year old rooted cuttings are planted in the month of January. In the centre of the pit, a small hole is made in which the roots are spread and the soil is pressed firmly and gently. The plants are irrigated just after planting. In order to ensure better establishment, only the strong, disease-free cuttings which have developed sufficient roots should be selected for planting. Before planting, the top of the plant is pruned to 3-4 buds, keeping single cane. A basin is prepared around each newly planted vine which is connected to the irrigation channel. As the plants start growing these can be trained on any one of the training systems.

Training

Training may be defined as the judicious removal of any plant part to give a proper shape. It also includes providing support, bending, tying and pinching to encourage side shoots, etc. In other words, it is the orientation of the above-ground vineparts. The main objectives of training include (i) to give a desired shape that facilitates different operations like cultivation, plant protection, pruning and harvesting, (ii) economical maintenance of the vineyard and (iii) to produce fruit of desired quality and yield.

After dormant season, the newly planted cuttings start growing as the atmosphere warms up. Two to three shoots may arise from the buds left on the cutting. These are allowed to grow for sometime and later on, one healthy, straight growing shoot is retained. The vine is allowed to grow single stem without allowing side-shoots up to certain height which depends upon the system of training to be adopted. The growing point is cut back up to desired height to remove apical dominance so that the branches can arise.

In the natural habitat, a grapevine is a robust climber but it can be trained on any fashion. There are numerous systems of training grapevines. In India, the most prevalent are : head, Kniffin, trellis and bower systems of training. The choice of training system shall depend on many factors such as apical dominance, vine-vigour, variety, bearing zone, sunscald problems, easiness to cultural operations, land use, climate and the capacity of owner to invest. An ideal training system is one which (i) facilitates different operations like pruning, culture, plant protection and harvesting ; (ii) spreads the fruits in the entire area provided for the purpose ; (iii) provides good leaf exposure ; (iv) avoids bigger wounds to the permanent parts of the vine : and (v) maintains the vitality of the vine over a long period. The training systems are illustrated in Chapter 2.

Under tropical climatic conditions in South India, the vines make vigorous growth and have pronounced apical dominance. Therefore, bower system of training is best suited there. While under North Indian conditions, bower as well as head systems are most prevalent. Some prevalent and best suited modes of training in India are described below :

Head system

This system is best suited to the varieties producing fruitful shoots from basal bud, e.g., Beauty Seedless, Perlette, Delight and Gold. It is the cheapest and easiest system of training vines like a dwarf bush. The vine is allowed to grow single stem with the help of stakes. After attaining a height of 1·2 metres, it is cut back to produce sideshoots. After keeping 4 laterals, 75 cm above the ground in all the directions, the rest of the shoot are thinned out. These laterals, cut to 2 buds at the first dormant pruning, will produce secondary arms. Generally, two arms of about 20-30 cm are kept on each lateral. At the second pruning, normally 1-2 fruiting spurs are kept on each secondary arm. After 3-4 years, the vine becomes like a dwarf bush and needs no stakes. The vines are planted 1·8 × 2·4 metres apart accommodating about 900 vines/acre. The spacing can further be reduced in basal bearing and less vigorous varieties. The advantages of this system include simplicity in shape, ease in training and inexpensive to establish. Cross-cultivation is possible. It is a popular system in wine-producing countries. However, the vines are slow to come into full production with the increased possibility of bunch rot and poor colour. Jindal *et al.* (1980) while comparing the popular systems of training for the severity of bud, flower and berry drop, found the maximum bud and flower drop in Beauty Seedless trained on head system.

Bower system

This system is also called Arbour or Pergola. This is the most popular system for Anab-e-Shahi in Andhra Pradesh. In Haryana, almost all the varieties are trained on this system. However, this is best suited for vigorous

varieties which do not perform well on other systems. In spite of being the most expensive, this is being adopted on a large scale almost in all the grape growing regions of India.

In this system, the vines are spread over a criss-cross network of wires, usually 2·1 to 2·4 metres above ground, supported by pillars (concrete, stone or iron) and arms of angle iron. Holes are drilled in the angle arms at distance of 60 cm to create a criss-cross network of wires. The vine is allowed to grow single shoot till it reaches the wire network. The vine is supported by bamboo sticks tied with jute string. When the vine reaches the wires, it is pinched off to facilitate production of side shoots close to the wires. Two vigorous shoots in opposite direction are selected at the wire level for training as primary arms. These are allowed to grow up to the space provided for the purpose. On each primary arm, three laterals on either side at a distance of 60 cm (along the wires) are kept as secondary arms. Thus, there will be 12 secondary arms on each vine. These secondary arms are allowed to grow and have about 8-10 tertiaries which after maturity form fruiting canes. The vines intended to be trained on bower system are planted at 3×3 metres apart. However, very vigourous vines like Anab-e-Shahi need still wider spacing at least under tropical conditions, where vines make luxuriant growth throughout the year without any dormant period.

It is the most expensive one amongst all the systems. However, it provides good protection to the crop against hot desiccating winds with ease in bird-scaring. It is also capable of giving higher yields. It has several defects also. Apart from being costly, pruning, training and spraying operations become difficult. The spray material cannot effectively reach leaves and shoots.

Kniffin system

The true Kniffin system, as originated by Mr William Kniffin of New York in 1850, is a four-cane system. In this system, two trellis of wires are strung supported by vertical posts. The vine is trained so that it has four canes, one along each wire and the bearing shoots hang freely with no tying being necessary.

Several modifications have been made in the original Kniffin system. There may be three horizontal trellis at different height. The modified Kniffin system as is prevalent in North India is known as double-arm-kniffin system. This system is not so common as bower system. It is best suited for moderately vigorous varieties. In this system, two wires are stretched horizontally at the height of 0·9 m and 0·6 m supported by iron angle poles at 4·8 metres distance. Two vines spaced at 2·4 metres are accommodated between two poles. The lines are kept 3 m apart. The vines, supported by bamboo sticks, grow single stem and one arm is allowed to develop horizontally along each wire on either side. Thus, each vine will have four arms. The bearing units and the renewal wood are regulated on four permanent arms while pruning. This system is suitable for Beauty Seedless, Early Muscat, Banqui-Abyad, Perlette, Bhokri, and Delight. This system is

cheaper when compared with bower system. The cultivation is possible only in one way. It has been observed that the lower arms become unproductive after some years and the arms produce wood mainly at the extreme ends only. This system is mainly confined to Research Institutes and it is not popular with the farmers in any of the regions of the country.

Overhead trellis

It is popularly known as Telephone system. This system is suitable for moderately vigorous varieties with more apical dominance. The chief demerit of Kniffin system, where the lower arms are rendered unproductive, is modified in this system by wires, stretched at one height like telephone wires. It is also an improvement over bower system in respect of ventilation and light penetration. It is relatively less expensive than bower, but more expensive than Kniffin system.

In this system, the vines are allowed to grow straight up to a height of 1·5–1·6 metres and then trained overhead on a canopy of usually 3 or 4 wires (45–60 cm apart) fixed to the cross-angle arms supported by vertical pillars or posts. The young growing vines are supported by bamboo sticks. After reaching the height of telephone (1·5 metres), the growing tip should be pinched off to encourage side shoots close to the wires. Two vigorous shoots (cross to wires) are selected as primary arms from which four vigorous laterals on each side along the wires are allowed to develop as secondary arms. Each complete secondary arm can carry 6–8 fruiting units.

This system is suitable almost for all the varieties. The usual spacing provided for each vine is 3×3 metres. This system is also not very popular with the grape growers except in Maharashtra, where it was first introduced at Urulikanchan (Pune).

While training vines on any of the systems (Kniffin, trellis or bower), it should always be kept in mind that the vine should develop the whole structure (primary and secondary arms, and tertiaries) slowly over a longer period, otherwise the arms become unproductive and produce fruiting wood only at the apical ends.

Pruning

Pruning refers to the judicious removal of any plant part to establish and maintain desired vine shape, to increase productivity and facilitate various cultural operations ; to distribute proper amount of bearing wood over the vine, and to regulate the crop for maitaining the vitality of vine and for consistent productivity. Pruning is the most important operation for the maintenance of fruitfulness and quality along with vigour of the vine. It should not be confused with training which mainly concerns with giving the form and the direction of the trunk and arms, and the position of shoots. The training determines the form, while pruning effects the functioning of the vine. It is done to concentrate

the activity of the vine to the parts left after pruning. Pruning is the most crucial operation and should be done with precision and care.

Certain principles should always be kept in mind while pruning grapes. Without proper knowledge of general principles of pruning, growth behaviour of vine in relation to pruning and the bearing habit one should not attempt pruning. The general principles of pruning fruit trees apply to vines also. Pruning, in general, has a depressing effect on vine and reduces the capacity of the vine to produce. Likewise, overbearing delays the ripening and reduces the capacity to produce. The vine produces its fruit buds in the axil of each leaf all along the shoots. Given proper conditions, all the buds regardless of their position, are potential fruit buds. However, a vine in a given season can properly nourish and ripen certain quantity of fruit without adversely affecting its vitality.

One must understand the meaning of the following terms before starting pruning.

The young leafy growth of the current season is a shoot which after maturity is known as 'cane'. The portion of cane (basal) left after pruning on the vine is called 'spur' and the spur intended to bear fruit, normally with 2–4 buds is a 'fruiting spur' and the basal part of mature cane with 8–12 buds that is left after pruning to produce the fruit is called 'fruiting cane'. The cane or spur cut back to one or two buds which is expected to produce fruiting wood for the next year is 'renewal spur'. When a fruiting cane/spur is chosen from the base bud of the renewal spur consistently, the arm is lengthened. Therefore, it should be shortened or replaced. So, any water sprout suckers arising from the arm directly is chosen as 'replacement spurs' which will produce growth for the following year. Arms are the branches older than one year and the undivided main stem is the trunk. Trunk and arms form the permanent framework of the vine. The arms have different units of pruning such as fruiting spurs, fruiting canes, renewal spurs and the replacement spurs.

When to prune

Depending upon the facilitation of the other vineyard operations, pruning can be done any time during dormant season. It can be started just after leaf-fall but must be completed before the start of growth in spring. There is little or no effect on the amount of food reserves of the vine if pruning is done during this period. Esau (1948) found the explanation for the same. She observed that during dormant period the sieve plates of the phloem remain blocked with a thick layer of callus, thus restricting the movement of carbohydrates. Early pruning usually fits in the other cultural operation. However, low temperature just after the growth initiation may damage the growing buds. If pruning is delayed much, excessive bleeding occurs, but it does not ordinarily cause much injury to the vine (Winkler *et al*, 1974). However, the sap contains about 2–4 gm of dry matter per litre of which about two-third is organic matter and one-third

inorganic substances. Reducing sugar and polysaccharides constitute the organic part and the nigrogen, potassium, calcium, phosphorus and iron are the inorganic components. The exudate also contains significant amounts of plant hormones like gibberellins and cytokinins (Skene, 1967 Skene and Ancliff, 1972).

Pruning is done once in North India during the month of January, while in South India, pruning is done twice a year ; once in summer and again in winter. Summer pruning is done during March-April in the States of Andhra Pradesh, Karnataka and Maharashtra, but in June in Tamil Nadu. The canes are cut back to 1-2 bud level for vegetative growth. It is also called back pruning or growth pruning. The winter pruning is done in the last week of September and the first week of October in Andhra Pradesh and Maharashtra, during the second and third week of October in northern districts of Karnataka and in December in Tamil Nadu. In this, the canes are headed back depending upon the bearing zone of the variety. The varieties like Bangalore Blue of Karnataka and Pacha Drakshi and Anab-e-Shahi in Tamil Nadu can give two crops a year. In such cases, instead of back pruning, normal pruning is done in summer also. Bangalore Blue is also known to respond well to staggered pruning.

How and how much to prune

The pruning consists of mainly thinning out and heading back. All the mature shoots (canes), whether those have given fruit or only made vegetative growth are to be headed back to a certain level which largely depends upon the bearing zone of the variety. Some of the canes are to be severely headed back to retain one or at the most two buds to serve as renewal spurs. This may be termed as thinning out. All the overcrowded, diseased and damaged canes are to be completely removed. The extent of thinning out or the number of fruiting canes or spurs to be retained after pruning largely depends upon the health and vigour of the vine, the system of training, space provided for each of the vines, fertility of soil, and the desired fruit quality and variety, etc. While the extent of heading back or in other words the number of buds left on the canes is a varietal feature. Some of the varieties like Perlette, Beauty Seedless, Delight, Bangalore Blue, Bhokri, Gold and Early Muscat produce fruit on the shoots arising from the basal buds on the cane. In such varieties, the canes are headed back to 4-5 buds. Such varieties are known as spur pruned varieties. On the other hand, in Pusa Seedless, Thompson Seedless, Kishmish Charni, Gulabi, etc., the canes are headed back to 8-12 buds. Such varieties are called cane-pruned varieties. Under North Indian conditions, the varieties Beauty Seedless and Perlette respond well to 2-3 bud level (Sharma *et al*, 1978 ; Sharma *et al*, 1977 ; and Khanduja *et al*, 1976). The diseased, weak and immature canes should be removed completely. About 50 per cent canes should be headed back severely to act as renewal spurs. The number of fruiting canes/spurs to be retained after pruning

are 8-10, 16-20, 32-40 and 40-50 vines trained on head, Kniffin, telephone and bower systems of training respectively.

Herbaceous pruning, i.e., removal of buds, shoots or leaves while they are green, is generally not followed under North Indian conditions. However, the suckers and water sprouts arising from underground parts and trunks need necessarily be removed.

Irrigation

Compared to other fruit plants, grapevines are more drought-resistant. However, for profitable production, adequate amount of moisture during growing season is a must. Commercial viticulture is possible only by the assured means of irrigation. Any water stress condition hampers growth and productivity of the vine, viz. the shoot growth decreases and the internodes become shorter, the tendrils droop, the leaf margins curl and the older leaves turn yellow. Under severe drought, the growing points may dry up and the young clusters at pre-bloom or bloom stage dry out. The berries shrivel and the leaves droop making the angle made by the petiole and lamina midrib wider.

The water requirement of vines are influenced by several factors. The time frequency of irrigation and the amount of water to be applied at each irrigation are determined by the soil type, climate, the kind of grapes and the time of ripening. The sandy soils which generally have poor water holding capacity require light and frequent irrigation. Likewise, the number of irrigations will be more under hot and dry conditions, compared to that in mild or humid climate. Addition of organic matter to the soil increases its water holding capacity. Under problematic soils like saline soils, frequent irrigation has to be applied to leach the salts.

The water requirement of a vine also varies at different stages of growth. Normally, the vines do not need any irrigation during dormant season. However, if there is a prolonged dry spell one or two light irrigations are necessary from November to January under North Indian conditions. All the parts of the root zone should be wet. If not irrigated during dormant period, the soil moisture depletes and reach very close to the wilting point by the spring. Under such conditions the resumption growth in spring is hampered. Therefore, it is necessary to replenish the soil moisture during dormant period. The first irrigation after dormant season should be applied just after pruning to encourage new vegetative growth. The second irrigation applied after about 25-30 days maintains sufficient moisture for better fruit set.

Nijjar and Sharma (1973) found that very little water was used by vine during the early growth stage (February-March). Nijjar and Randhawa (1968) stated that frequent heavy irrigations before fruit set encourage vegetative growth and suppress fruiting. The irrigation to vines at bloom should, therefore, be avoided.

The period between fruit set to maturity is the most critical when adequate moisture should be maintained in soil. Any water stress during this period deteriorates the yield and quality. The interval of irrigation during this period be 7-10 days, depending upon the prevailing temperature and other environmental should factors. Nijjar and Sharma (1973) found that the vines utilised the maximum amount of water from the middle of May to the end of June under Ludhiana (Punjab) conditions so, the interval between two irrigations should be reduced during this period. It should always be kept in mind that prolonged flooding in the active growing season may damage the root system and the vines may show symptoms of water stress. Irrigations should be stopped when the berries start ripening and a slight shortage may hasten the process. Excessive moisture at this stage can cause great loss due to rotting of berries as a result of splitting and the quality also deterioratesd. Severe drought at ripening stage also affects the quality and yield adversely. Irrigation to vines after harvest is as important as during active growth period. In order to maintain sufficient moisture in the soil, irrigation should be applied up to October at an appropriate interval depending upon the distribution of rains. The irrigation should be stopped in November to force the vines to enter dormant period. Under South Indian conditions, the irrigations are given at weekly intervals during the period from summer pruning to the onset of rain and thereafter, at 10-12 days' intervals until winter pruning. Water requirement is more in the South as the vines do not enter dormant period.

Water is the most scarce input in Indian agriculture. Therefore, the efficient water management is a very important for vine growing also. Dhankar *et al.* (1981) found that 31 per cent water could be saved by leaving one metre strip unirrigated in between the rows spaced at 3 × 3 metres in 11 years old Perlette vines trained on Kniffin system, without affecting the yield and quality. They found that there was no lateral movement of water in the unirrigated strip. Likewise, use of different kind of mulches also effectively conserved soil moisture (Chakrawar, 1977 ; Patil, 1975). The studies conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri, showed that when there was water shortage, kaolin spray can help the crop to retain more moisture and increase the yield as compared to control under stress conditions (Anon, 1979).

Manuring and fertilisation

A grapevine removes an appreciable quantity of nutrients from soil both in terms of wood and fruits. It has been estimated that an average crop of grape removes from the soil 40-60 kg N, 10-15 kg P and 50-70 kg K per hectare (Nijjar, 1970). These values are in addition to the nutrients removed by wood and leaves. Therefore, to maintain the soil fertility for consistent yields, it becomes necessary to replenish these nutrients. It can be done with the application of

manures and fertilisers applied through soil or foliar applications, in addition to that already used for pit filling.

The major nutrient elements required in comparatively larger amounts include nitrogen, phosphorus, potassium, calcium, magnesium and sulphur, while the micro nutrients necessary for growth and fruiting are boron, iron, manganese, zinc, molybdenum, copper and chlorine. Growth and fruiting of a vine is affected adversely if any of these elements becomes deficient or in short supply. The grapevine does not show the deficiency symptoms until it becomes acute to retard growth and fruiting. Therefore, visual deficiency symptoms may not be a good criterian to find out the requirement of a particular element. However, certain specific symptoms appear on leaves, twigs or flowers when a particular element is in short supply. Likewise, some nutritional disorders are bound to occur when a particular element is in excess and it also imbalances the nutrient status.

Nitrogen deficiency results in lighter green foliage accompanied by reduced shoot growth which ultimately affects the production. Red or yellow leaf colouration between the main veins of leaf appear in magnesium deficient vines. The potassium dificiency symptoms roughly resemble that of magnesium. In both the cases, the symptoms appear at the leaf margins, but with potassium, the colour changes first to pale green or bronze while yellow or white in magnesium deficiency. Finally, the tissue dies which is referred to as leaf scorch. In severe cases, the bunches become compact with small berries and uneven ripening. black leaf is also caused due to potassium deficiency. Manganese, zinc, boron and iron are the micro elements generally found deficient especially in alkaline soils where these are rendered unavailable. Manganese deficiency causes chlorosis between the primary and the secondary veins of basal leaves. In contrast, zinc deficiency symptoms appear on the apical leaves of the main shoot and the leaves on the lateral shoots remain small which is referred to as 'little leaf'. Low zinc also causes poor berry set resulting in very loose bunches. the iron deficiency symptoms also appear on apical leaves but with a different pattern from that of zinc deficiency. The leaf becomes yellow or creamy white. An early and clear symptom of boron deficiency is the development of a mottle chlorosis from the leaf margin. As the deficiency becomes severe, the chlorotic patches mix up and become necrotic from the leaf margin. The leaves become small and brittle. The shoot growth becomes restricted due to short thick internodes. Boron deficiency results in reduced yields due to heavy drop of unopened buds and flowers resulting into poor berry set which is referred to as 'coulure'. Another most important symptom of boron deficiency is the development of small seedless berries (shot berries) which is attributed to poor pollination. Such a condition signifying the presence of different sized berries is known as 'hen and chickens' or 'millerandage'.

Determination of requirement

The fertiliser requirement of a grapevine is influenced by various factors such as the fertility status and other characteristics of the soil, age and vigour and yield potentiality of the vine, climate of the region and the vine management. Therefore, the recommendations made for a region may not hold good in the entirely different climatic zone, variety or conditions. The most pertinent example to signify this fact was put forth by Chundawat *et al.* (1977) who found that grapevines in Haryana were overfertilised. They found very high negative correlation in respect of yield with N, P and K. The fact behind this was that in the absence of reliable data of fertiliser trials, the farmers followed the heavy fertiliser recommendations of the South where generally the soils are shallow and the vines do not enter dormancy.

Apart from visual deficiency symptoms (which are not always reliable) ; there are other methods of predicting the nutrient requirement of the vines. For some particular elements, laboratory test may provide help in finding out the nutrient requirement. For example, nitrogen deficiency can be detected by nitrate colour test (Cook and Kasimatis, 1959). Similarly, argenine levels in grape berries may also prove useful for detecting nitrogen deficiency. Argenine levels in dormant canes and mature fruits correlate well with the amount of nitrate in petioles and pruning weights (Kliewer and Cook, 1974).

Tissue analysis is the most reliable and dependable tool to find out the nutrient status of vines. Leaf petiole is almost an ideal vine part for determining the nutritional status of the grapevine (Cook, 1966). The petiole samples for analysis should be collected at the time of full bloom as suggested by Cook and Kishaba (1956). The critical value for deficient, normal and excess of a particular element are set for a given variety (Cook, 1966).

The nutrient status as evidenced by petiole analysis is not a constant factor. Apart from varietal differences (Brar *et al.* 1979), the bearing and non-bearing conditions of a vine (Selvaraj and Shanmugavelu, 1981) and the seasonal fluctuations (Bindra *et al*, 1979) also show variation in the tissue composition. In order to find out the general nutrient status of the vines in a given area, nutritional surveys have been conducted to make certain recommendations to the growers. Divte (1967) conducted one such survey in Poona region for Cheema Sahebi (S-7). Similarly, subsequent surveys have been conducted around Bangalore for Bangalore Blue, Anab-e-Shahi and Thompson Seedless (Srinivasan and Subrahmaniam, 1979), around Hissar for Perlette (Khera *et al*, 1980) ; for Anab-e-Shahi and Thompson Seedless in some orchards located in Karnataka and Maharashtra (Bhargava *et al*, 1981) ; and around Hyderabad for Anab-e-Shahi (Ramesam *et al*, 1981).

Recommendations made from the actual fertiliser trial of a specific variety under a given set of conditions are the most reliable. With the introduction of

All India Coordinated Fruit Improvement Project. some fertiliser trials were started in the different grape growing regions of the country, such as Bangalore, Coimbatore, Hyderabad and Ludhiana many of which are yet to be concluded.

At a recently concluded workshop (1982) of the Project held at Nagpur, the following recommendations were made for adoption in Anab-e-Shahi.

(i) For vines in the age group of 3-5 years, application of 500 kg N + 125 kg P_2O_5 + 750 kg K_2O/ha/year.

(ii) For vines above five years of age, application of 500 kg N + 500 kg P_2O_5 + 1000 kg K_2O/ha/year.

These recommendations are for a vine population of 750/ha (4·5 × 3 m spacing). The fertilisers are to be applied in split doses, i.e., at April pruning 60 per cent N, 50 per cent P ; and at October pruning 40 per cent N, 50 per cent P and 50 per cent K, the rest 50 per cent K should be applied at fruit set. These recommendations were made based on the data from a nutritional trial conducted during 1970-78 at IIHR, Bangalore.

Likewise, the trial at Ludhiana on Perlette has provided useful data for over a decade. It is yet to be concluded. However, the consistent best response has been obtained with 2 kg of CAN containing 25 per cent N, 4·5 kg of superphosphate (16 per cent P_2O_5) and 0·8 kg of K_2O applied per adult vine of five years or more, planted at 3 × 3 m distance. For younger vines, the above-mentioned doses are to be reduced in proportion to age. The fertiliser recommendations from Haryana for a grown up vine spaced at 3 × 3 m are 75 kg of farm yard manure, 1·25 kg of ammonium sulphate, 2 kg of superphosphate and 0·8 kg of potassium sulphate (Yamdagni, 1980).

Time and method of application

Grapevine has a deep and widespread root system. Dasradhi and Afzalunnisa (1972) suggested that active feeding zone was in the range of 30-40 cm deep. Therefore, at the initial stage, the vine mainly takes nutrients applied for while filling the pits. Whatever extra manures and fertilisers needed are applied at a distance of 30 cm from the trunk in the circular ring during the first year. In the subsequent years, these are applied in the 15 cm deep furrow opened in the rectangular or square plots made around the vines and then covered with soil from the alternating ridges. The whole amount of fertiliser should never be dumped around the trunk, rather it should thoroughly be spread and mixed in the soil over the root area of the vine. The farm yard manure may be applied in January. Half of the nitrogen and potash and the whole amount of phosphorus should be applied immediately after pruning in February under North Indian conditions. The remaining half of nitrogen and potash are to be applied just after berry set (April).

Another method of supplying nutrients to grapevine is through foliar application. This method is comparatively more effective for rapid recovery of

plants and efficient use of fertiliser. Under high soil pH conditions, most of the micro-nutrients are rendered unavailable. Therefore, these nutrients are to be supplied through foliar sprays. The important micro-nutrients generally supplied by this method include iron, zinc, boron and manganese. Foliar application of boron through sprays at bloom and pre-bloom stages have been found to improve the yield and quality of Thompson Seedless variety of grape (Kumar and Bhushan, 1978 ; Yamdagni *et al*, 1979). The most effective concentration was 0·2 per cent boric acid. Likewise, the total soluble solids (TSS) are increased with 0·05 per cent iron sprays (Rana and Sharma, 1979). Kumar and Bhushan (1978) found that application of micro-nutrients (Zn, Mn, B) through foliar sprays, apart from improving yield, quality and vigour of the vine, also increased the uptake of N, P and K. Yamadagni *et al*, (1979) reported that spray of 0·2 per cent zinc sulphate increased the number of bunches at harvest (reduced panicle drying) and their weight and there was tremendous increase in yield as a result of improved berry set. Efforts have also been made to supply potassium, through K_2SO_4 (Singh *et al*, 1979) and calcium by $CaNO_3$ spray (Gupta *et al*, 1980) to improve eating and keeping quality of Perlette grapes. Micro-nutrient sprays apart from being effective in improving the yield, quality and growth of vines, improved berry set and berry retention. Dabas and Jindal (1981) found increased pollen viability and germination as a result of magnesium sulphate (0·3%) and boric acid (0·1 0·3%) sprays on Thompson Seedless. These treatments helped in reducing bud, flower and berry drop and also reduce panicle drying, a serious malady of Gold and Thompson Seedless in Haryana (Jindal and Sharma, 1982). Application of boric acid alone and in combination with trunk girdling reduced bud and flower drop resulting in better berry set ; improved berry retention, yield and quality (Jindal *et al*, 1982). However, boric acid application did not show any additive effect.

8.8 Growth

Growth

The grapevine has a definite cycle of growth, flowering, berry set and berry development leading to ripening and harvest. Under temperate climate and also in subtropical climate of North India, the vine sheds its leaves and enters dormant period. In southern India, the grapes do not shed their leaves naturally. The vines are normally pruned only once during January in North India, while twice in March and October in South India. As the temperature rises and reaches about 10°C, the buds begin to swell and green shoots emerge from them (bud break). The buds of the vine may be vegetative or reproductive. The vegetative buds give rise to a shoot that bears only leaves, while the reproductive buds are mixed buds that give rise to a shoot which normally bears one or more

clusters of flowers. The two buds can be distinguished by observing under dissecting microscope with clearly visible flower cluster primordium.

The temperature during the summer months (March-June) governs the time of bud-burst or bud-break, bloom and ripening as well as quality of berries. The temperatures between 28-32°C are most congenial for the development of all parts of vine (Khanduja, 1974). After bud-break, with the rise in temperature, the shoots grow rapidly in length and thickness. The leaf arises at the node and bears buds in the axil. Full bloom usually occurs 6-8 weeks after bud-break under North Indian conditions depending upon the variety and the prevailing temperatures. The rapid shoot growth usually slows down during blooming time. This does not cease the growth completely by forming terminal buds as in many other tree fruits.

8.9 Flowering, Pollination and Fruit set

The process of flower initiation for the next year's crop starts before bloom and the development of different parts continues until about harvest time. The different parts of flower calyx, corolla, stamens and pistils are differentiated in the order named. The grape flowers are borne in clusters which appear to be lateral to the shoots.

The flower cluster consists of many small greenish individual flowers which may be perfect, pistillate (reflexed stamens) or staminate.

Blooming (caps or calyptras fall from flowers) progresses for several days on a vine and even the flowers within a panicle do not bloom at one time. A variety is generally considered in full bloom when, on an average 50 per cent calyptras have fallen. When the calyptras fall, the pollens are released which fall on the stigma and germinate under favourable conditions. The pollen tube reaches embryo-sac through the style and the sperm fertilises the ovule. There are usually four ovules, two in each half of the ovary which form seeds. Berry set generally results from pollination and fertilisation and seed development. However, some varieties set by parthenocarpy, the berry set without fertilisation. Only the stimulus from pollination is required for berry set in Black Corinth which set parthenocarpically. In other seedless varieties (Perlette, Beauty Seedless, Pusa Seedless, Delight, Thompson Seedless) fertilisation occurs but the embryo subsequently aborts, which is termed as 'stenospermocarpy'. In certain other varieties where abortion is delayed, the seeds remain hard and empty.

According to Winkler *et al.* (1974) self-pollination is a rule with vinifera grapes. However, cross-pollination is not only possible but under certain conditions desirable and necessary (reflexed stamens varieties such as Hur, Banqui Abyad, Katta Kurghan). Several days after bloom, there is a heavy drop of berries (defective or unfertilised ones). The berries, those do not fall from the cluster, are

said to have set. Any appreciable and detectable increase in berry size is also referred to berry set stage. The berry set and development are controlled by growth substances and their interactions. Predominantly ones are gibberellins, auxins, cytokinins, ethylene and inhibitors. In some varieties the clusters set poorly and are small. Underdeveloped, seedless berries, those fail to enlarge are shot berries. Such a condition is known as 'millerandage' and may be aggravated by bad weather at pollination and heavy crop loads. Poor pollen viability and germination also lead to flower drop, resulting in poor set (Jindal and Dabas, 1982).

8.10 Fruit Growth and Development and Improvement of Quality

The berry growth in terms of increase in volume, fresh weight, dry weight and diameter is characterised by a double-sigmoid curve. There are three stages of growth. The first and the third rapid growth stages are separated by less growth and no growth stage which is termed as 'lag phase'. These three stages are more pronounced in seeded grapes (Weaver, 1976). However, Rao and Pandey (1976) observed double-sigmoid pattern of growth in Pusa Seedless variety under Delhi conditions.

In the first stage, the ovary and the contents (except embryo and endosperm) grow rapidly mainly by cell division. In the second stage, the embryo and the endosperm make rapid growth with slight or no growth of the ovary. In the third stage, rapid growth of mesocarp results in final swell of the berry followed by maturation. The suspended growth during the second stage or lag phase coincided with the higher levels of endogenous growth inhibitors (Rao and Pandey, 1976). The treatment of berry at lag phase with Ethrel (250 ppm) has been reported to hasten ripening by about a week under Delhi conditions (Rao *et al*, 1974). Chauhan *et al*, (1981) found that dipping of bunches in 500 ppm Ethrel at veraison stage increased berry size, improved quality and advanced ripening under Hissar conditions. Veraison is a stage when berries begin to colour and soften, it is the beginning of the third stage.

The ripening begins when the berries start to colour and soften. The colour of red and black varieties becomes more intense, while in the others the green colour turns into white or yellow. The sugar content increases with simultaneous decrease in acidity. The berries at the apical portion ripen the last. When the grape has passed the desired peak in quality, the overripe stage starts. The acid content continues to decrease and the sugars become concentrated due to evaporational losses. In some varieties, berries shrivel. At this stage, the fruits are more prone to fungal diseases.

Techniques of Improving Fruit Quality

It is obvious that good quality grapes will fetch premium price in the market. In table grapes good quality represents medium-sized clusters of uniformly large

berries with the characteristic colour, flavour and texture of the variety. Seedlessness is another important requirement of quality table grapes. Apart from many general factors like variety, agroclimatic conditions, cultural and management practices and plant protection measures which effect the quality, there are others which directly influence it. These include crop regulation (pruning, thinning), girdling and the use of plant growth regulators. It is beyond the scope of this chapter to discuss them in detail. The techniques most pertinent to our country which either being adopted by the growers or advocated by the scientists are given in the subsequent paragraphs.

Crop regulation

Pruning is the cheapest and easiest way of crop regulation. Heavy crop load impairs the quality and delays ripening, therefore balanced pruning is considerded essential. The number of fruiting units and their length should be proper so that the vine can nourish and ripen the crop.

Excessive bearing of vines can be reduced by cluster or berry thinning. Thinning of flower cluster consists of removing underdeveloped, mis-shaped clusters between leafing out and blooming. It is advisable not to practise severe flower cluster-thinning in the varieties where there is a problem of poor set and panicle drying such as Thompson Seedless and Gold under Haryana conditions (Jindal and Sharma, 1982). Under such conditions, cluster thinning which is done after berry set should be practised. It is advisable to keep about 60-70 clusters per vine spaced at 3m x 3m trained on bower system. Slight reduction in the crop load can be done by berry thinning which consists of removing part of clusters. Singh *et al*, (1980) have advised that the apex of clusters should be removed immediately after cluster thinning. Likewise, thinning is known to reduce uneven ripening and improve colour development in Beauty Seedless (Sharma and Jindal, 1981). Apart from improving quality, thinning also advances ripening.

Girdling

The technique consists of removing complete ring of bark from any part of vine such as shoot, cane, arm or trunk. The detailed studies at Hissar (Dabas *et al*, 1980) have shown that the best response to girdling was that of 0·5 cm wide ring of bark from trunk which usually heals within a month. It can be done for improving berry set and yield at one week before bloom, to increase berry size at or just after berry set, at the beginning of colour change to advance ripening, uniform colouration and for better eating quality. Over-cropping of girdled vines should be avoided to get the proper response of pruning (Nath *et al*, 1973). In order to have still better effects, girdling may be combined with other treatments such as thinning and application of growth regulators or other treatments such as boron (Jindal and Bakshi, 1972 ; Jindal *et al*, 1982). Continuous girdling of vines for 6 years have shown that there is no deteriorating effect on the

vine growth as the girdles heal up in a short time and the carbohydrate need of roots is very low.

Growth regulators

Among the different growth regulators tried on grapes, 4-chlorophenoxyacetic acid (auxin), gibberellic acid (gibberellins) and Ethrel (ripening hormone) command a special place and are being used. 4 CPA is very beneficial in increasing berry set (Bajwa *et al*, 1972) and reducing berry drop (Sharma and Jindal, 1982). Gibberellic acid (GA_3) applications are made for different purposes such as to loosen the bunch, increase the berry size, and improve the yield and quality of grapes. For different purposes, the applications are made either by spraying or by bunch dipping in different concentrations at different stages of berry development. The concentrations also depend upon the variety and the climate. Normally, lower concentrations are used in comparatively warm areas. Singh *et al*, (1980) have recommended that 40 ppm gibberellic acid should be applied either by spraying or bunch dipping at flowering and again at berry set in Thompson Seedless, Delight and Kishmish Charni under Haryana conditions. Gibberellic acid applications can be combined with thinning or girdling (Jindal and Bakshi, 1972). Recently, Ethrel is being used mainly to advance ripening and improve quality. Its application also improves colouration and helps in uniform ripening. Generally, it is applied at veraison stage or when colour change starts or berries start softening. Application of Ethrel (250 ppm), 5 weeks after anthesis under Delhi conditions resulted in increased berry weight, sugar content, reduced acidity and hastened ripening by a week (Rao and Pandey, 1981). Spray of aqueous solution of Ethephon (500 ppm), four weeks after berry set produces attractive coloured berries and increases TSS/acid ratio (Singh and Chauhan, 1980 ; Chauhan *et al*, 1981). The optimum concentrations for each region and variety are to be standardised properly otherwise higher concentrations may cause berry drop. When girdling was done in addition to Ethephon application, it did not show any additive effect in var. Gold (Sainju, B. R. personal communication).

Apart from these techniques, regular water supply, application of potassic fertilisers, foliar feeding of vines with boron, zinc and iron, and control of insects-pests and diseases are also essential for improving the yield and quality in grapes.

8.11 Pests and Diseases and Physiological disorders

Pests

There are about fifty pests found attacking grapevine and its fruit in different grape growing regions of the world. In India, we are fortunate to have only a few of these. Insects constitute the major population of pests. However, sometimes mites, nematodes, honeybees or wasps and birds also assume the

importance as pests. The nature of damage caused by important pests and their control are summarised below :

Flea beetle (*Scelodonta strigicollis*) : Feeds on tender growth by cutting holes. Spraying of 1 kg DDT (50 w.p.) or 500 ml Malathion (50 EC) or 1½ kg Carbaryl (50 w.p.) in 500 litres water per acre is effective.

Thrips (*Thipiphorothrips cruentatus*) : Sucks plant sap from lower leaf surface, produces silvery bloches which turn yellow, leaves wither and drop. Spray 1 kg DDT (50 w.p.) in 500 litres water/acre. During ripening, spray 500 ml Malathion (50 EC) per acre.

Chaffer beetle (*Adoratus* spp.) : Feeds voraciously on leaves during night leaving only the veins ; hides itself during day time. Dusting of 10% BHC at an interval of 10 days is suggested.

Scales : Small insects found below the bark. Suck sap from shoots which dry up. Leaves turn yellow and growth stops. Removal of loose barks after pruning and spray with 0·1% Folithion 2-3 times are recommended.

Termites : Damage the roots of the plants, make trunk hollow and vines dry up. Mixing of 30 gm Aldrin 5% dust per pit at the time of planting and application of 5 ml Aldrin 30 EC in 5 litres water in basin of each vine are recommended.

Wasps and honeybee : Spoil ripening berries, feed on sweet juice. In home vineyards bunches may be covered with olive green muslin cloth bags. The nests should be destroyed by spraying BHC 50 w.p. 40 gm in 10 litres of water or BHC 10% dust after sunset.

Birds : Cause considerable damage to ripening berries by direct feeding and damaging the packed berries. This adds to trimming costs. In home vineyards, bunches may be covered with olive green muslin cloth bags. The large vineyards are covered with nylon netting. Bird scaring with traditional methods should also be adopted.

Nematodes : Damage the roots, growth is adversely affected, leaves turn yellow and drop. Slowly the vine dies. Application of DBCP 33·69 litres a.i./ha is effective. (Krishnamurthy Rao *et al.* 1972).

Diseases

Grapes are susceptible to a number of diseases mostly caused by fungus. There is more spread of diseases under humid-summer conditions. Summer rains accompanied by high temperature are especially harmful. However, unlike most other fungal diseases, powdery mildew develops well in dry climate. The diseases of common occurrence in India are anthracnose, downy mildew, powdery mildew and dead arm.

Anthracnose : This is by far the most widespread and destructive disease in the vineyards, especially in North India. This is caused by a fungus *Elsinoe ampelina* which continues to survive in affected canes and is disseminated in the rainy season through rains.

The fungus can infect all the green parts of the vine including fruits. Dark brown spots with darker margins are formed on leaves around midrib and main veins. However, the lesions on canes are elongated, sunken, dark brown with dark purple raised margins. On the berries, the spots are initially light brown in colour but as they grow in size they turn grey at the centre surrounded by a reddish or purple margin.

The most effective control measures include the affected parts should be destroyed just after pruning and the vines should be sprayed immediately with 0·2% copper oxychloride containing fungicides. Spray vineyards on leaf emergence with 0·2% Benlate or Bavistin. Repeat the same spray after one month. At least 4 sprays of these fungicides should be given during the rainy season (after harvest) at fortnightly interval.

Downy mildew : This disease is more serious in South India. This is caused by fungus *Plasmopara viticola* which prefers cool humid weather for its spread. This fungus infects leaves, flowers and young berries. Light yellow translucent spots appear on the upper leaf surface. Later on, white mould patches develop on the lower surface of the leaf.

Severely affected leaves finally dry and drop from the vine. Succulent shoots, petioles and tendrils have a water soaked appearance. In severe cases flowers and young fruits are also affected and killed which drop off. At later stages, the berries wither, turn brown and then shrivel and shatter easily from the bunch.

Spraying of 1·0 per cent Bordeaux mixture repeatedly at 6-7 days' interval is still the most widely adopted control measure.

Powdery mildew : This is caused by fungus *Uncinula necator*. Unlike most other fungi which are favoured by moist condition, powdery mildew develops well in dry climate.

This fungus attacks leaves, tender shoots and fruits. Whitish grey patches appear on leaves and berries. Patches spread on the whole leaf and young berries, may drop off when affected severely. Developed berries, which do not ripen properly, become hard and crack.

The control measures include spraying of wettable sulphur (0·2%) or dusting sulphur at 5-7 days' interval during infestation. Spray of 0·1 per cent Karathane is very effective in checking the spread of the fungus.

Physiological disorders

Blossom-end rot : A black sunken spot develops at the blossom-end of the berry which later on spreads with water soaked region around it. Defective

calciumn nutrition and assimilation appear to be cause for it. Spray of 1·0 per cent calcium nitrate may correct this disorder.

Interveinal chlorosis : This is another nutritional disorder where the area in between veins becomes yellowish. It may be due to magnesium, zinc or iron deficiency. These deficiencies can be corrected by spraying vines with 0·2 per cent sulphate salts of the nutrients (neutralised $MgSO_4$, $ZnSO_4$ and $FeSO_4$). Likewise, under high salinity conditions, marginal chlorosis, which is followed by progressive necrosis of leaf blade towards petiole, may occur. As already discussed, soils containing more than 0·3 per cent salts should be avoided for grape cultivation. Magnesium deficiency may be aggravated by excessive fertilisation of vines with potash.

Bud, flower and berry drop : This problem is recent in India. As a result of heavy drop of buds, flowers and subsequent berry drop, the bunches become very loose and unattractive. Apart from heavy reduction in yield, such bunches fetch low price. This problem is present in almost all the varities in hot dry areas of North India. Chundawat and Jindal (1981) have identified three main drops including complete panicle drying in some varieties. They have attributed this menace to improper nitrogen application, carbohydrate nutrition, improper fertilisation of berries, heavy crop load, uneven ripening and auxin deficiency at a particular stage of berry development. No fungus seems to be associated with the menace. However, it may be aggravated due to improper plant protection measures. To control bud, flower and berry drop, the following measures can be effective :

(i) By making 0·5 cm wide girdle from the trunk of vines about 10 days before full bloom, bud and flower drop can be reduced resulting into better set. This also reduces subsequent berry drop (Chundawat *et al.* 1979). Proper C/N ratio may be maintained by judicious fertiliser application under a given set of climatic conditions.

(ii) Application of 500 ppm Ethrel at ripening stage in Beauty Seedless results in even ripening, thereby reducing the possibility of pre-harvest drop. Dipping of bunches in NAA containing Planofix/Microfix 100 ppm (a.i.) solution about 10 days before ripening reduces berry drop in Beauty Seedless (Chundawat and Jindal, 1979).

(iii) Heavy irrigation at bloom should be avoided.

(iv) This problem can also be reduced by regulating yield per vine. Application of benzyl adenine (200 ppm) and 4 CPA (20 ppm), in addition to thinning, also reduce berry shattering (Sharma and Jindal, 1981 and 1982).

Bud killing

Formation of limited number of buds and bud killing have been reported to be associated with poor productivity in Thompson Seedless and its clones (Jindal

and Dabas, 1982a and 1982b). About 50 per cent of the differentiated buds are found more or less shrivelled and brownish-black in colour when examined under microscope. These fail to sprout and result in heavy yield reduction. This may be due to excessive nitrogen application (Chundawat *et al*, 1977). Bindra and Chauhan (1976) suggested that under high N conditions, some phyllosphere fungi may become parasitic causing bud mortality. No direct association of fungus has been ascertained so far. Anthracnose may aggravate the menace. Some more work is required in this direction to ascertain the real cause and time when the buds are killed. Girdling and exogenous applications of auxins have been found to reduce the bud mortality in Thompson Seedless grapes (Dabas *et al*, 1980; Jindal and Dabas, 1982b).

8.12 Harvesting

Grapes do not ripen after they are harvested, so must be left on vine until they are fully ripe. Different maturity standards are followed to find out the proper time of harvest. The grapes are considered ripe when the fruits have reached the condition best suited for the intended use. In table grapes, consumer acceptability should always be considered above all the maturity standards. It should always be kept in mind that at harvest, the grapes should be attractive in appearance, have good eating and keeping quality and reach the market when the prices are most favourable. Ripening is indicated by the increase in sugars (degree Brix) and decrease in acidity, and the development of colour, flavour and texture characteristics of the variety. These changes almost stop when the grapes are harvested. Total soluble solids are generally used to determine the maturity of grapes as it has a high correlation with palatability. However, relative amounts of acidity and TSS effect the taste. A variety may be more palatable with even low TSS provided the acidity is also low, e.g., Gold. Therefore, acidity at a given Brix is also very important. So maturity standard can also be predicted to some extent on the basis of TSS/acid ratio (Makhija *et al*, 1982). Most of the growers take colour and softening along with taste as the maturity standards for harvesting grapes.

The time taken from fruit set to ripening largely depends upon the variety, crop load and the atmospheric temperature. Therefore, for a given locality and variety, the number of heat units (degree days) required for ripening may be calculated which provides a suitable standard for deciding the harvesting time. The ripeness of the individual bunch is judged by observing the berries at the distal end of the cluster which are the last to ripe.

While harvesting, the cluster should be handled only by the stem so that the natural appearance is not impaired due to rubbing of the bloom. The clusters should be removed from the vine by cutting with a sharp knife near its attachment

to the cane. The harvesting should be done during the cool hours of the day, i.e., early morning or evening. Before packing, the clusters should be properly trimmed by removing broken, decayed or otherwise defective berries and pre-cooled. The bunches can be graded accordingly to fetch better price in the market.

8.13 Yield

A properly managed vineyard can be expected to start yielding after 3 years under North Indian conditions and even less than 2 years under tropical conditions of peninsular India. It can satisfactorily be maintained at least for more than two decades. However, individual vine may live up to half a century or more. In some varieties like Thompson Seedless, Pusa Seedless or other related ones, there is a tendency that the bearing potentiality decreases with increasing age after taking about 4-5 full crops. In such cases, the vines can be renovated by heading back near ground level after taking 5-6 crops and then training the most vigorous shoot to the pergola.

Compared to other grape growing countries of the world, the vineyards in India give very high yields, especially in peninsular India. Balasubrahmanyam (1981) reported that yields of the order of 60 tonnes/ha, probably the highest in the world, are not uncommon in well-maintained Anab-e-Shahi vineyards. A well-maintained vineyard of Perlette may yield around 25-30 tonnes/ha in North India and that of Pusa Seedless or Thompson Seedless around 15-20 tonnes. However, the yield is quite a variable factor and is influenced greatly by the region, care and management, varieties, agroclimatic conditions and other cultural practices including pruning. For proper management of post-harvest operations like packing, storage and marketing, it is now possible to forecast yields by microscopic examination of buds (Chadha *et al*, 1978 : Khanduja, 1976).

8.14 Packaging and Storage

In our country, many types of containers are used for packing grapes. In Maharashtra, cylindrical bamboo baskets were in use for quite a long time. Now, progressive growers of Sangli area in Maharashtra use corrugated paper boxes with butter papers, paper cuttings and alkathene bags. They pack the grapes after proper grading and fetch good price in different cosmopolitan cities of India as well as abroad. Balasubrahmanyam (1981) reported that Maharashtra exported to gulf countries, in 1981, two lakh boxes (four kg each) of Thompson Seedless grapes and the figure might have gone higher by now. Bamboo baskets

are generally used for packing in North India with dried grass or paper cuttings as packing material. The use of wooden boxes is limited.

Grape being a perishable commodity, faulty handling, packing or storage conditions aggravate the spoilage. Pre-harvest application of fungicides or growth regulators has been found to increase the shelf life of the fruit and reduce spoilage (Randhawa *et al*, 1976; Mann and Dhillon, 1979; Ravis and Sukla, 1979; Rao, 1981). The pre-harvest spray of 10 per cent calcium nitrate reduced the weight loss and decay when the grapes were stored for 3 days at room temperature (Gupta *et al*, 1980). Grapes can economically be stored up to 40-45 days in cold storage (Randhawa *et al*, 1977; Mann and Dhillon, 1979; Bhullar *et al*, 1980). The grape growers of Sangli district in Maharashtra (personal communication) are able to store grapes safely for 2 months with the use of 'grape guard' in cold storage. Grape guard is a paper impregnated with potassium metabisulphite which is kept at the top of each box. This paper releases SO_2 for fumigation under high humidity conditions. It has two-way action, i.e., just after packing, SO_2 is quickly released, and then during cold storage, there is slow release of SO_2. This was developed by Dr Nelson of USA and is being imported from there.

8.15 Breeding and Varietal Improvement

The common objectives of a grape improvement programme are to produce locally adapted high yielding varieties with quality that is desirable for the intended use. In India, we are mainly concerned with table grape along with some emphasis on raisin and juice grapes. Ideally, new table variety should be attractive, seedless, high yielding, high sugar with good palatable fruits and resistant to the diseases and pests. In addition, the varieties intended for growing in North India, should ripen before the onset of South-Western monsoon to avoid spoilage due to rotting. No such limitations are necessary for South Indian grape growing tracts where there is a relatively long, free-from-rain fruiting period. However, early ripening varieties may help in extending the season. Therefore, a continuous programme of grape improvement is essential as the consumer's requirements as well as the adaptation of the existing varieties are liable to change over a period of time due to occurrence of new strains of pathogens, pests and other disorders.

In order to fulfil the set objectives or in other words, to have a desired variety, different systems can be adopted.

Introduction

The varieties developed and selected at other places, indigenous or exotic, may be introduced and assessed for the local adaptability. This is the easiest and most

common in our country. Most of the varieties grown commercially like Perlette, Thompson Seedless, Delight, Beauty Seedless, Cardinal, Pearl of Casaba, Early Muscat, etc., have been introduced, assessed and released for cultivation. To facilitate this work, National Bureau of Plant Genetical Resources has been established. Most of the present varieties have been introduced from California in USA, USSR, Yugoslavia and Australia.

Changes in the phenotypes of grape occur due to natural or controlled hybridisation, or mutations. A variety which is in cultivation over a long period may carry many natural mutations. Likewise, grape being a highly heterozygous crop, segregates characteristics when raised from seeds, thus creating a wide range of variability. Such phenotypic variability provides great potentialities of selection of a variety with desired characters. As already discussed under 'varieties', the commercial variety Cheema Sahebi is a seedling selection from Pandhari Sahebi. Likewise, Gopalkrishna and Phandis (1960) reported a new variety of grape selected from the seedling of Pandhari Sahebi. Pusa Seedless selected at Indian Agricultural Research Institute, New Delhi, is another example. Singh *et al.* (1974) selected a very early ripening clone from 432 vines of Perlette.

Hybridisation

Natural or controlled inter- and intra-specific hybridisation with consequent segregation of characteristics results in wide phenotypic variability. In order to combine the desired characteristics, the knowledge of inheritance of these characters is very important. The knowledge regarding the general and specific combining ability of the varieties is very essential for making choice of parents in restricting the cross-combination and thereby seedling population for better selection. The conventional approach of producing inbred lines for their utilisation in the production of heterosis is not being favoured in grapes. This is mainly because of high genetic load and longer time required in obtaining reasonable homozygous lines. Pollen culture to produce haploids and their diploidisation, if made possible, may help much in this context.

Most of the *vinifera* varieties are self-fertile. However, cytological barriers to sexual reproduction may exert their effect before fertilisation, resulting in seed abortion. Crosses between different *Euvitis* species can easily be made. However, the crosses between *Euvitis* and *Muscadinia* which differ in chromosome numbers, are made with difficulty as most of the resulting hybrids remain sterile.

Pollen of *M. rotundifolia* will fertilise the egg of *V. vinifera* but the reciprocal is less successful. Partially fertile F_1 hybrids $(2x-39)$ can cross reciprocally between themselves or with *V. vinifera*, but with *M. rotundifolia* only when the latter is used as male parent (Jelenkovic and Olmo, 1968). Various methods have been tried to overcome the sterility of *Euvitis* × *rotundifolia* hybrids. These include crossing of certain specific *Euvitis* species ; backcrossing partially fertile hybrids

with one of the parents for one or more generations ; doubling of the chromosome number of the parent species, etc. However, the grapes are outbreeders and the varieties are highly heterozygous and carry a load of deleterious recessives. Inbreeding depression is reverse so that by the second or third generation, sterility may again be imparted. Therefore, the most successful breeding method is to maintain heterozygosity by crossing the best parents selected after taking into consideration the inheritance of desirable characters and the general and specific combining ability of the varieties. Heterozygosity is maintained as the propagation is done by cutting and hence once a desired seedling is obtained, it can easily be propagated and maintained. Many of the present varieties were obtained by this method. Some of the important varieties are listed below along with their parents.

	Variety	*Cross-combination*
1.	Perlette	Scolokertekhiralynoje 26 (Hungarian) × Sultanina Marble (Russian)
2.	Delight	Scolokertekhiralynoje 26 (Hungarian) × Sultanina Marble (Russian)
3.	Cardinal	Tokay × Ribier
4.	Beauty Seedless	Queen of Vineyards × Black Kishmish
5.	Rubired	Alicante Ganzin × Tintocao
6.	Royalty	Alicante Ganzin × Trousseau

Recently, the following four hybrids have been named and released for cultivation from IIHR, Bangalore by Negi and Randhawa (1980).

7.	Arkavati	Black Champa × Thompson Seedless
8.	Arka Kanchan	Anab-e-Shahi × Queen of Vineyards
9.	Arka Shyam	Bangalore Blue × Black Champa
10.	Arka Hans	Bangalore Blue × Anab-e-Shahi

Many potential grape hybrids have also been reported from the grape breeding programme at the Indian Agricultural Research Institute, New Delhi, which after large-scale testing may provide a number of varieties for North India (Singh *et al*, 1972 ; Jindal *et al*, 1982).

Grape hybridisation work begins just before the vine flowers. Different hybridisation techniques are discussed below :

Choice of parents

Based on the knowledge of inheritance of desired characters and the combining ability of the varieties used as parents, a programme of hybridisation is chalked out for the season. Before deciding for the use of a variety as female parent, it is necessary to know something of the seed viability and germination. It has been found that in some varieties when used as female parent or selfed the seed germination is poor or not at all. Cardinal is one such variety. If such varieties

are needed as parents, these should be used as male. Critical appraisal of hybridisation work done at IARI showed that Banqui-Abyad, Hur and Angoor Kalan are the best female parents for the intended objectives of earliness, seedlessness and good quality. Likewise, Beauty Seedless, Perlette and Pusa Seedless when used as male parents impart these characters in the seedlings. In order to induce seedlessness in the progeny, it would be advisable to select varieties having high seed index as female parents (Olmo, 1946 ; Weinberger and Harmon, 1964). Recently, Jindal *et al*, (1983) have suggested that for inducing seedlessness in the progeny, the varieties Banqui-Abyad, Katta Kurghan and Hur should find place as female parents. Their observations are based on the high seed index of these varieties which have been confirmed from the seed content of the progeny.

Emasculation and pollination

It is considered necessary to study the floral biology of the varieties to be used as parents under the conditions prevailing at the place. Results of the studies conducted on these lines in northern India showed that anthesis in grape varieties started early in the morning and maximum flowers opened between 8 a.m. and 9 a.m. ; dehiscence took place immediately after anthesis : pollen fertility was above 80 per cent and the stigma became receptive one day prior to anthesis and remained so one day after anthesis (Randhawa and Sharma, 1960).

The flower clusters of both the parents are bagged one day before crossing after removing opened flowers, if any. The flower buds are emasculated with the help of a pair of forceps. Two diagonal pulls at the top after cutting the base of the parianth along with some filaments, removes all the calyptra along with anthers. Any anther, still sticking, should be removed carefully. Jindal *et al*. (1983) reported that from introductions being maintained at IARI, some varieties (Hur, Angoor Kalan, Banqui-Abyad, Katta Kurghan) were found to be of reflexed stamen type, which when used as female parents, do not need emasculation. These have even otherwise been valued for quality and imparting seedlessness to the progeny also. Thus, very tedious task of emasculation by forceps is unnecessary in such varieties and enables the breeder to attempt much more combinations. It is advisable to select varieties as parents with overlapping flowering period. However, Moti (1972) reported that pollen stored at room temperature without control of humidity remained viable only for 10–25 days but when stored at 0, 10 or 25 per cent RH, the storage life was enhanced up to 8 months, which can further be extended even up to 14 months if stored under deep freeze at 0 per cent RH. The emasculated bunches are bagged and pollinated the very next day. The injured stigma will turn black and can be removed. Randhawa *et al*, (1965) have suggested to do the controlled pollinations between 9 a.m. to 11 a.m. when dehiscence occurs in maximum anthers under Delhi conditions. Controlled pollination is normally done by cutting a

previously bagged, freshly blooming cluster and tapping it gently against an emasculated cluster, which is immediately bagged again or by applying pollen with a brush or some atomiser devised for the purpose.

The method of grape seed germination has been described under propagation.

Shortening the juvenile period and selection at the nursery stage

The long period from seed to fruit (3-5 years) could, perhaps, be shortened by forcing vegetative growth in nutrient sand cultures in a greenhouse and pruning to stimulate the fruitful buds into growth (Wagner, 1967). The raised seedling can be grafted/budded onto bearing vine to obtain fruits early for assessment (Negi and Olmo, 1971a). Another method to enhance fruiting is to transform tendrils of the primary and lateral shoots into inflorescences (Srinivasan and Mullins, 1980). Mullins and Rajasekaran (1981) suggested a method for fruiting cuttings after initiating root without shoot growth and subsequently treating the growing tip with plant growth regulators.

Apart from forcing flower in seedling at an early stage, certain correlations between morphological or biochemical characters and the desired characters in fruits may provide the breeder with a tool to discard or select the hybrids at an early stage. This will help in reducing the space and labour in addition to restricting the size of population for critical selection. Wagner (1967) observed correlations in respect of certain characteristics such as sex and muscat flavour. The use of some biochemical methods of selection at the earliest possible stage of seedling development is necessary and work on these aspects is almost lacking.

Field planting and selections

When the seedlings are about 15-30 cm high, they can be transplanted directly in the field in rows spaced at 3 metres and about 50 cm between the seedlings within a row. These are trained to form a head. These should continuously be assessed (3 years at least) for stability of character before making any selection. The selected hybrids are multiplied for large-scale yield trials and climatic adaptability.

Somatic mutations

Natural or induced mutations are important sources of variation in grapes. Heritable changes that occur either in individual gene or involve the whole chromosome are known as 'mutations'. The changes may occur naturally or can be induced by certain chemicals or irradiation. Natural 'sports' are also mutations and often single gene changes. A variety which is in cultivation for a long time may accumulate many mutations, some of which may remain latent without any expression. The new characteristics which appear due to a change may be of economical significance.

In grapes superior clones have been selected, tested and released (Olmo, 1964). Selection of these improved clones (high yielding) is very advantageous. Likewise, suppression of low yielding clones has also been reported (Woodham and Alexander, 1966). Seedless mutant of seeded varieties do have much significance for table purpose (Olmo, 1940; Muthuswamy and Khader, 1959). Similarly, a seeded mutant was found in seedless Black Corinth (Harman and Snyder, 1936). The other mutations may occur in colour of berry or other parts, such as variegated leaves, hairyness of leaves, and berry size, particularly small.

Technique of inducing mutations

The mutations are generally induced by irradiation of dormant buds or cuttings with different dosages of 'X' or gamma rays; thermal neutrons or chemicals such as ethyl methane sulfonate (EMS), *N*-nitroso-*N*-methyl urethane (NMU t), etc., (Olmo, 1960; Das, 1971; Sharma and Mukherjee, 1972). Irradiation of rooted cuttings should be preferred as root formation is affected by irradiation (Pratt, 1959). Size of cuttings or the number of buds on each cutting may influence their survival. Freshly prepared cuttings with 3 buds gave better survival in Pusa Seedless (Sharma and Mukherjee, 1973). The success in inducing mutations also depends upon the concentration of the mutagen. A dose which permits survival of more than 50 per cent (LD 50) of the plants and which induces mutations is nearly 2000 rads (2 kR). Upadhyay (1973) found that gamma radiation above 4 kR was 100 per cent lethal to dormant buds and in cuttings there was no survival beyond 3 kR dose. The dose of 2 kR was best for Bhokri and Pusa Seedless. Among the chemical mutagens like *N*-nitroso-*N*-methyl urea (NMU), NMUt and EMS, 0·04 per cent NMU was found to be the most effective. For seeds, the irradiation doses are generally higher.

Induced mutations are attempted when a certain variety lack in one or more important character. Without altering the whole genetical set up, mutations may occur in a particular gene responsible for that particular character. This can be illustrated by the work of Olmo (1960) who got a partially sterile form of the seedless Perlette which has loose clusters and does not require as much hand thinning as does the original Perlette, thus making it more potential for commercial adaptation.

Polyploidy

Polyploidisation of grapes is of immense importance in improvement of table grapes especially to increase the size of berries. Tetraploids can also be used in breeding to obtain triploids. However, in crosses with diploids more viable seeds are produced by using the tetraploid as the pollen parent (Alley, 1957).

Polyploidy can be induced by giving certain treatment and it may also occur spontaneously. A polyploid branch may arise from a latent bud near a pruning

wound. Detection of polyploid branches is done usually by their large berries, chromosome counts in pollen mother cells or other tissue and the size of somata. Retarded growth of shoots, larger and greener leaves and a u-shaped sinus are other characters useful for early detection of polyploid shoots. Narsimham and Mukherjee (1970) found that tetraploids characterised by empty seeds also ripened earlier than those of the corresponding diploids.

Technique of inducing polyploidy

Colchicine is generally uses as an aqueous solution of 0·25–0·50 per cent with 5–10 per cent glycerine to induce polyploidy (Das and Mukherjee, 1967). Several applications of the solution are made on the shoot tip of growing bud. Sometime, the solution is injected into the bud and growth regulators may be added in the solution to increase its efficacy. Almeda (1952) obtained 3x and 4x seedlings by applying heat shock to the inflorescences.

Polyploids have been obtained spontaneously or induced but have not become so economically important.

Allotetraploids are more promising compared to autotetraploids which are of little use (Olmo, 1976). Autotetraploids have poor cultural characteristic, being less fruitful, irregular in berry size, more fragile and the root system is weaker. The triploids in grapes are generally highly sterile and may be potential for using as vigorous rootstocks.

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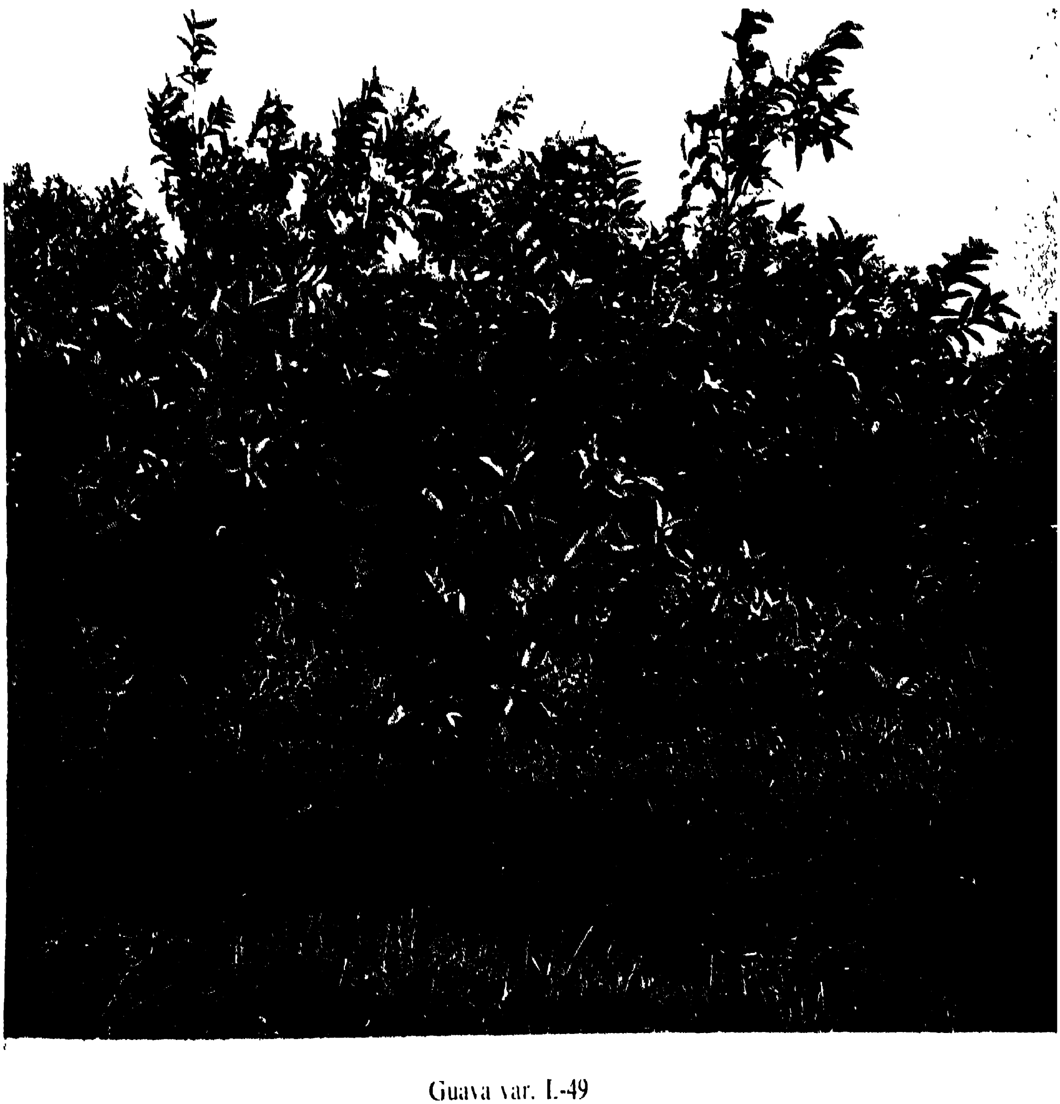

Guava var. L-49

Guava in bearing

9

GUAVA

S. K. MITRA and T. K. BOSE

Guava (*Psidium guajava* L.), the apple of the tropics, is one of the most common fruits in India. It claims to be the fourth most important fruit in area and production after mango, banana and citrus. It is now widely grown all over the tropics and subtropics and has become the most common of the newly introduced subtropical fruits in Israel. Records suggest that it has been in cultivation in India since early 17th century and gradually became a crop of commercial significance. Guava is quite hardy, prolific bearer and highly remunerative even without much care.

9.1 Composition and Uses

Guava is a rich source of vitamin C and pectin. According to Phandis (1970), guava contains 82·50 per cent water, 2·45 per cent acid, 4·45 per cent reducing sugar, 5·23 per cent non-reducing sugar, 9·73 per cent total soluble solid, 0·48 per cent ash and 260 mg vitamin C per 100 gm of fruit, which differ with the variety, stage of maturity and season. Millar and Bazore (1945) stated that the guava in Hawaii is a fair source of vitamin A, but a poor source of thiamine. However, Campos (1943) reported that guava is a good source of both thiamine and riboflavin. In general, the pink-fleshed varieties are poor in vitamin C content than the white-fleshed ones (Golberg and Levy, 1914) and it varies between 55 to 529 mg per 100 gm (Cruess and others, 1945). It contains much iron, but 80 per cent of this is in the seeds, and not utilisable (Miller and Bazore, 1931). It is also a fair source of calcium and phosphorus.

Guava fruit is relished when mature or ripe and freshly plucked from the tree. Excellent salad and pudding are prepared from the shell of the ripe fruit. Guava jelly is well known to all and the common sour wild guava makes the best jelly. In some of the varieties, acid and pectin are so concentrated that three

times of sugar may be added to the juice yielding 300 lb of jelly from 100 lb of fruit (Abbott, 1931). It can also be canned in sugar syrup or made into fruit butter. Its juice is used for the preparation of 'sherbets' and ice cream. Guavas contain vitamin C 2 to 5 times more than fresh orange juice, and dehydrated guava juice powder is a source of vitamin C. It freezes exceptionally well and the frozen product is practically indistinguishable from fresh fruit (Ruehle, 1948). In some countries the leaves are used for curing diarrhoea, and also for dyeing and tanning.

9.2 Origin and Distribution

It originated, along with a number of other fruits, in tropical America and seems to have been growing from Mexico to Peru. It is grown in Ceylon from sea level to an elevation of 5000 feet (1515 m) and throughout Burma. At present the major guava producing countries are southern Asian countries, the Hawaiian Islands, Cuba and India.

It is believed to be introduced in India at a very early date, as it is mentioned by Bruton who was in India early in the 17th century, and occupies nearly 1,25,327 acres (50,740 ha) of land (Hayes, 1970). Though it is successfully grown all over the country, the most important guava-growing states are Uttar Pradesh (23,000 hectares), Bihar (6,850 hectares) Madhya Pradesh (3,738 hectares) and Maharashtra (2,700 hectares). Uttar Pradesh is by far the most important guava-producing state of India and Allahabad has the reputation of growing the best guava in the country as well as in the world.

9.3 Species and Varieties

Species

The genus *Psidium* contains about 150 species (Hayes, 1970). The Brazilian or Guinea guava *P. guineense* has small fruit with poor fruit quality. The common guava, *P. guajava* var. Aromaticum yields small size fruit while the fruits of *P. pomiferum* is round and that of *P. pyriferum* is pear-shaped in nature. The mountain guava, *P. montanum* is a shrub of about 1·5 m high with flat round branchlets. Fruits of Chinese guava, *P. friedrichsthalianum* are small and globose in shape with high acid content. Next to common guava, the Cattley guava, *P. cattleianum* is considered as the most important species. This is a shrub or small tree 3–6 m in height and fruits are small, deep scarlet in colour, mainly globose in shape. The fruits of *P. cattleianum* var. Lucidium are sulphur yellow in colour and the trees are comparatively large in size. The common guava was formerly classified as *P. pyriferum* and *P. pomiferum* based on their shape.

Varieties

Varietal description of guava was started with the work of Firminger as early as in 1863, followed by Watt (1908), Macmillan (1914) and Popenoe (1920). The nomenclature of the different varieties (clonal) of guava grown in India has not yet been established. Some varieties were named according to shape, colour or smoothness of the skin, while several other varieties like Allahabad, Banarasi, Harijha, Kerala, Baruipur, etc., were named after their place of origin. In India, the guava varieties of Bombay were described by Cheema and Desmukh (1927), the varieties of Uttar Pradesh by Smith (1934) and Teaotia *et al.* (1962), the varieties of Andhra Pradesh by Ibrahim (1943), those of Bihar by Roy and Ahmed (1951), those of Assam by Dutt (1953) and those of northern Madhya Pradesh by Tripathi *et al.* (1971).

The variation, in plant growth, yield and physico-chemical composition among the different guava varieties, has been reported by several workers. Cheema and Deshmukh (1927) named the variety Sind, which produces round or elliptic fruits with soft white or reddish pulp; variety Lucknow, bushy tree and fruits round with somewhat acidic in nature; variety Nasik, the fruit of which is elliptical. Roy and Ahmed (1951) described the varieties Harijha, Habsi, Safeda and Seedless and concluded that varieties other than Habsi can be successfully used for breeding. In Assam, many non-descript varieties were found to grow and named according to locality and language such as Madhuri-am (Assam valley plains), Safri or Payere (Cachar), Soh-Pryia (Khasi Hill) and Am-Sophri (Garo Hills). Ramansomayazulu (1953) recommended that L-49 (Lucknow-49) guava can be grown well at high altitudes of Araku valley.

Selection B-30 was named after J. H. Beaumont and was described by Bowers and Nakasone (1960) as the most promising variety because of its bright pink colour, acidity and freedom from off flavours. Ahmed (1961) reported that in West Pakistan the most widely grown variety Safeda produced excellent fruits of large size. Teaotia *et al.* (1962) in their studies with Chittidar, L-49, Allahabad Safeda, Seedless, Red Fleshed, L-42 and Kerala, found L-42 as most suitable variety for canning and Allahabad Safeda suitable for cultivation in dry tract. In Hawaii, Campbell (1963) described about the two new guava varieties—Blitch and Patillo. Blitch was suitable for jelly making, while Patillo for cooking. In studies with guava varieties Srivastava and Srivastava (1965) noticed that fruits of Allahabad Safeda were high in brix, pH acidity, ascorbic acid and sugar content whereas Red Fleshed were richer in starch, crude fibre and tannin. Sehgal and Singh (1965) reported that variety L-49 produced fruits of excellent quality with greater fruit size, and the number of seeds per fruit was less than that of Chittidar and Safeda. Due to its outstanding performance L-49 was recommended for growing in Punjab by Bakshi and Randhawa (1967), although Safeda, Chittidar and Seedless were also considered suitable.

Nathani and Srivastava (1965) in their detailed study with 14 varieties concluded that the variations among the different varieties of guava were mainly in respect of fruit shape and size, colour and texture of ripe fruits and pulp. Safeda was clearly recognised by its whitish fruits having greater firm pulp than other varieties. The varieties Safeda and Chittidar showed some interesting features. Chittidar could be easily distinguished by the presence of red dots on the fruits (Sehgal and Singh, 1965; Mitra, 1983). Safeda also often had red dots, though a few in number, globose in shape and smaller in size. Other workers had described the fruit of Safeda as round and Teaotia *et al*, (1968) described the fruits of Chittidar as roundish ovate.

The term red-fleshed covers the various shades of pink-fleshed fruits. Teaotia *et al*, (1969) reported that Ankapalle, Red-Fleshed, Super Acid, Florida Seedling, Hybrid Red Supreme, Arica Florida, Portugal, China Surkha, Kothrud, Patillo and Allahabad were among the red-fleshed varieties. Golberg and Levy (1941) observed that pink-fleshed varieties in South Africa were usually poor in vitamin C content compared to white-fleshed fruits.

In variety Seedless, though the fruit is of good quality and has only few seeds, the bearing is very poor with small size fruits. It was, therefore, not considered as a variety of commercial importance (Sehgal and Singh, 1965). Singh *et al*, (1979) recommended that L-49 guava proved to be an ideal variety in the orchard, considering the average yield per tree, fruit weight, sugar, acidity and vitamin C content of the fruits. Chadha *et al*, (1981) and Mitra (1983), in comparative evaluation of different varieties also reported L-49 as the best among the varieties tested.

Salient characteristics of some important guava varieties are given below:

Lucknow-49 : It is a selection made at Poona. (Cheema and Desmukh 1927) also known as 'Sardar guava'. Semidwarf tree, 2·3 to 3·4 m tall, vigorous, heavy branching type, crown flat. Leaves large, 12·8 to 13·2 cm long, 6·8 cm broad, elliptic-ovate to oblong in shape. Fruits roundish ovate in shape. Skin colour primrose-yellow with occasional red dots on the skin. Taste sweet and keeping quality excellent.

Allahabad Safeda : This is the most popular variety of Uttar Pradesh Tree vigorous, medium tall, 5·8 to 6·2 m, branching heavy with dense foliage, tendency to produce long shoots. Crown broad and compact. Leaves 9·5 to 9·8 cm long and 4·8 cm wide, elliptical to oblong in shape. Fruits medium, average weight 180 gm, roundish in shape, skin colour yellowish white, keeping quality good.

Banarasi : This is one of the sweetest guavas, lacking acidity. Tree medium to tall, 4·2 to 5·4 m in height, crown broad. Leaves long, 10·0 cm to 10·4 cm in length and 5·4 cm in width, oblong in shape with acute apex and base obtuse. Fruits round and dresden-yellow in colour. Keeping quality medium.

Harijha : This is also an useful variety because of profuse bearing. Tree medium, 3·5 m, medium vigour and sparsely branched. Leaves medium, 8·2 to 8·6 cm in length, 3·2 cm in width, lanceolate, apex acute and base round. Fruits round in shape, greenish-yellow in colour. Taste sweet and keeping quality excellent.

Chittidar : A tall tree, 5·0 to 5·8 m, rounded crown, spreading branches. Leaves large, 12·2 cm to 12·8 cm long and 5·72 cm broad, elliptic-ovate to oblong elliptic in shape, apex acutely pointed, base round. Fruit sub-globose in shape, straw-yellow in colour, red dots few and scattered. Taste sweet and keeping quality good.

Apple Colour : Tree medium ; 4·0 to 5·2 m in height, crown broad, spreading growth. Leaves 10·4 cm in length and 5·7 cm in width, elliptical in shape. Fruits spherical in shape, dawn-pink in colour with deep minute dots on the surface. Taste sweet and keeping quality good

Baruipur : This is one of the important commercial varieties of West Bengal. Tree medium to tall, 4·2 to 5·4 m in height, spreading growth, crown broad and compact. Leaves 10·0 to 10·4 cm long and 5·4 to 5·6 cm broad, oblong in shape. Fruits round in shape, dresden-yellow in colour with white flesh. Keeping quality medium.

Behat Coconut : Tall tree, 4·8 to 5·3 m, moderately vigorous, crown flat and branching heavy, bark colour dark brown. Leaves large, 12·8 cm long and 6·4 cm broad, ovate-lanceolate in shape and sometimes twisted. Fruit round, aureolin in colour, fruit surface rough with dots. Taste sweet and keeping quality good.

Pear-shaped : Tall tree, 6·0 to 6·8 m in height, growth erect and upright, branching medium. Leaves medium, length 10·2 cm, breadth 4·6 cm, elliptical in shape, coarse and leathery. Fruits pyriform in shape and straw-yellow in colour. Fruit surface smooth with large dots. Keeping quality good.

Red Fleshed : Tree vigorous, medium tall, 3·5 to 4·8 m, spreading branches, crown vase-form and open. Leaves 9·8 to 10·4 cm in length and 4·8 to 5·2 cm in breadth, elliptic-oblong in shape. Fruits roundish-ovate in shape, saffron-yellow in colour, few red dots present on the surface The flesh colour is dawn-pink. Keeping quality poor to medium.

Seedless : A tall tree with rather long trunk, 5·2 to 5·8 m in height, upright branches. Leaves large, 13·6 to 14·0 cm in length, 7·2 cm in width, oblong in shape. Fruits oblong to globose in shape, straw-yellow in colour. Flesh thick and creamy white in colour. Keeping quality excellent.

Physico-chemical composition of fruits of some varieties is given in Table 1.

TABLE 1. PHYSICO-CHEMICAL COMPOSITION OF FRUITS OF SOME GUAVA VARIETIES (Mitra, 1981)

Varieties	Length of fruits (cm)	Diameter of fruits (cm)	Fruit weight (gm)	Total soluble solid (Brix)	Total sugar (% fresh weight)	Ascorbic acid mg/100 g of pulp
Allahabad Safeda	5·4–6·4	6·2–6·9	86·5–160·6	8·4–10·5	6·8–8·5	106·0–187·9
Apple Colour	5·0–5·6	5·0–6·2	80·2–120·2	7·8–9·2	6·2–7·3	116·2–194·6
Banarasi	5·1–6·2	5·8–6·4	92·8–132·6	9·2–9·3	6·8–7·7	93·0–172·6
Baruipur	5·6–6·3	6·0–6·2	88·6–125·6	8·8–9·2	6·8–7·6	103·9–182·2
Behat Coconut	5·8–6·1	5·4–6·0	82·2–156·8	9·0–9·4	6·8–7·7	88·8–168·0
Chittidar	5·6–6·6	5·8–7·2	95·6–148·6	8·2–9·0	6·4–7·9	96·4–182·8
Harijha	5·5–6·4	5·8–6·8	81·8–135·2	8·6–9·2	6·3–7·9	92·3–164·6
Lucknow-49	5·8–6·6	6·4–6·5	95·8–145·0	9·2–10·0	6·8–8·8	132·5–216·0
Pear-shaped	5·4–6·2	5·8–6·0	78·8–130·8	8·8–9·6	6·7–7·5	75·2–157·4
Red Fleshed	5·2–6·3	5·3–6·0	91·2–135·6	8·2–8·8	6·2–7·6	62·5–144·6
Seedless	4·2–5·0	4·8–5·3	70·8–86·8	8·4–9·2	6·7–7·4	83·3–168·2

9.4 Soil and Climate

Soil

Guava trees are very hardy and can thrive on all types of soil from alluvial to lateritic, but they are sensitive to waterlogging. It can, however, be grown on heavier but well-drained soil. The best soils are deep, friable and well-drained. In Florida, the guava thrives on light soils with a pH value as low as 4.5 and on limestone with a value up to 8.2. Its cultivation should not be extended in saline or alkaline soils. The root distribution studies by the direct excavation method revealed the maximum concentration of roots between 0–20 cm soil depth indicating that the active absorption was close to the surface of the soil (Hegde and Tiwari, 1981), which leads to suggest that at least the top soil should be rich.

Climate

Guava is successfully grown under tropical and subtropical climate. In areas having distinct winter season, the yield tends to increase and quality improves. It can grow from sea level to an altitude of about 5000 ft, (1515 m). It grows best with annual rainfall below 40 inches (1016 mm) restricted between June to September. The young plants are susceptible to drought and cold conditions. Although it requires dry atmosphere at the time of flowering and fruiting, high temperature at the time of fruit development causes fruit drop.

9.5 Propagation

Guava is propagated from seeds and also by vegetative methods.

Seed propagation

Seedling trees bear fruits of variable size and quality, but such trees are generally long-lived. Normally fully matured seeds of the current season are used for sowing. The seedlings can be raised in the nursery or in polythene bags. The seedlings raised in polythene bags can be transplanted in the field when they are six to eight weeks old. In guava, the seeds lose viability within a short period after extraction. The usual practice is to sow the seeds immediately after extraction. Extension of storage life and invigoration have been possible only to a limited extent through the use of different chemicals. But only meagre information regarding seed treatment for maintenance of vigour and viability is available. Haq *et al*, (1973) reported that soaking in cold water had beneficial effect, but treatment with hot water was harmful. Seeds could be stored for

104 days, when they were pre-soaked in ferulic acid at 10^{-3} M concentration. Potassium nitrate at 1 per cent and para-hydroxybenzoic acid (10^{-3} M) were also effective in retaining seed viability of guava (Ghosh, 1978).

Vegetative propagation

Guava can be successfully propagated by cutting, air-layering, grafting and budding.

Cutting

Although guava is hard-to-root, results of investigation indicate that it can be successfully propagated from cutting under mist. Blommaert (1958) observed that softwood cuttings of two local commercial guava varieties gave 75-90 per cent rooting in sand culture under intermittent mist when treated with IBA. Teaotia and Pandey (1961) reported that both NAA and IAA at 50 ppm and 100 ppm encouraged rooting of semi-hard wood etiolated cuttings. According to Jolioceur (1962) optimum rooting of 44 per cent was obtained after one month under mist, treated with IBA at 0·08 per cent. Sen *et al*, (1967) also recorded 100 per cent rooting in the leafy cuttings of guava under intermittent mist by treatment with IBA. Bhandari and Mukherjee (1969) observed that green-wood cuttings taken from young seedlings and about 10 year-old grafts of Allahabad Safeda gave 100 and 90 per cent rooting respectively when etiolated and ringed for 39 days and treated with 5000 ppm of IBA at the time of planting. Dhua *et al*, (1982) reported 93·3 per cent rooting in semi-hard wood cutting under mist with *p*-hydroxybenzoic acid (200 ppm) and IBA·(5000 ppm) treatment as quick dip.

Air-layering

Air-layering is one of the most important commercial methods in practice for propagation of guava. Shoots selected for air-layering should be 1 cm in diameter and preferably from previous year's growth. A ring of bark about 3 cm long is removed and covered with sphagnum moss, previously soaked in water and wrapped with polythene film. The ends of the film are carefully tied and left for rooting. It takes 30-40 days for rooting in the monsoon. An improved method of air-layering was described by Ruehle (1948). Shoots about 1·5 cm in diameter was girdled by removing a strip of bark about 1·5 times the width of shoot. The girdled portion was coverd with a ball of moistened sphagnum mass and wrapped with translucent rubber plastic film. After root formation in 3-5 weeks the shoot was detached and planted in rich compost. Rainy season was found more favourable than spring for air-layering. Ahmed (1964) reported only 6·9-10·0 per cent moisture loss in air-layering of guava during the rainy season ; 60 to 80 per cent callus formation took place within 15 days and root development occurred within a month of layering. Chandra (1965) found high percentage of success with air-layering when layers were treated

with NAA. Bhatt and Chundawat (1982) reported that ringing of branches followed by etiolation by wrapping black polythene on ringed portion 6 to 7 weeks before the application of rooting media proved effective in the regeneration of roots. Said and Inayatullah (1966) reported that a media consisting of soil, sand and leaf mould in the proportion of 1 : 1 : 1 resulted in better rooting in the layers.

Stooling

Majumdar and Mukherjee (1968) reported a method in which air-layers were grown for 3–5 years and then cut back and allowed to shoot. These shoots were ringed and applied with IBA in lanolin and earthed up to induce rooting : when rooted, the shoots were separated and planted in nursery beds or pots.

Grafting

Inarching is another important method of propagating guava : this technique may yield up to 95 per cent success but is more laborious than cutting or layering. Nelson (1954) reported the success of veneer grafting and suggested that the scion should be selected from terminal growth flushes in which the stem was green and quadrangular with well-developed axillary buds. Veneer grafting with green-wood scion was recommended for top working (Tamburo *et al.* 1955). They also recorded 73 per cent success when scions were wrapped with vinyl film. Besides these, the side grafting method in which the vertical flap of the rootstock is retained and tied over the scion during operation is also now in practice.

Budding

The technique involved in budding is of selecting a proper rootstock. The rootstock is prepared by removing side growth up to 20-25 cm from the base. Different budding techniques like Forkert shield, patch, chip, etc., have been tried in guava with different degrees of success. Patch budding on stump shoots (1·2 to 1·9 cm in diameter) proved successful in guava (Dedolph and Bowers, 1960). Jaffee (1970) developed 'Green chip' method of budding on guava seedling (5 mm in diameter). He suggested that this method can also be adopted successfully for top working on older trees. Srivastava (1962) compared the different methods of budding of guava and concluded that plants propagated by Forkert method grew better than those by patch or shield budding. Forkert method of budding was found to give consistently better result than shield or patch budding (Chandra, 1965).

Rootstock

In some fruit plants, rootstocks exert a great influence on vigour, cold resistance, fruitfulness, fruit quality, mineral composition of leaves and disease tolerance of the scion, but very little information is available on guava (Shankar,

1967). Several species of *Psidium* such as *P. cujavillis*, *P. molle*, *P. cattleianum*, *P. guineense* can be suitably used as rootstock of guava. The Chinese guava (*Psidium friedrichsthalianum*) has been found to be resistant to wilt disease of guava and to be a compatible rootstock. The dwarfing effect of the Chinese rootstock could be used in commercial planting (Edward and Shankar, 1964). The trees grafted on *P. pumilum* had a dwarfing effect and *P. cujavillis* produced the largest but non-uniform and rough skinned fruits. Fruits from trees on Florida seedling stock had the highest total acidity (Teaotia and Phogat, 1971). The Chinese guava was also found to be resistant to *Meloidogyni incognita* and suitable as a rootstock in nematode affected areas (Fernadezdiaz-Silveira, 1975). Singh *et al.* (1976) have observed that Allahabad Safeda guava, when grafted on *P. pulmilum*, the sugar content of fruits increased considerably while the ascorbic acid content was found to be increased by grafting on *P. cujavillis* stock. The yield response was, however, more by using *P. cattleianum* as rootstock for Allahabad Safeda. A pathogenic green algae, *Cephalsuros* sp. was found to affect seriously the leaves and fruits of guava in southern Florida. Marlatt and Campbell (1961) reported that varieties Patillo and Blitch had a low disease incidence, Ruby × Supreme 6-29 was moderately susceptible while Webber × Supreme and Ruby × Supreme 10-30 were most susceptible to the disease.

The rootstocks frequently produce shoots particularly at the early stage in budded or grafted plants and they should be removed.

9.6 Cultivation

Planting

Before planting, the field should be deeply ploughed, harrowed and levelled. The pits about 1 metre cube should be dug before the monsoon at appropriate distance in the square system of planting. After 15 to 20 days, the pits should be filled with 25-30 kg of decomposed farm yard manure mixed with surface soil. Planting of seedlings and clones usually starts by the onset of monsoon. The earth should be well pressed to keep the plants firmly in position.

Plant density

Guava is commonly planted at a distance 12 to 18 feet (3·6 to 5·4 m), close planting at 10 feet (3·0 m) distance is still not known. Rangacharalu (1954) suggested at least 25 feet (7·5 m) distance between the plants.

In guava, the total number of fruits per plant and the number of fruits of different grades were not much influenced at the early stage by plant density, but high density planting had an adverse effect on the quality of fruits. The contents

of total soluble solids, total sugar, reducing and non-reducing sugar and ascorbic acid were significantly reduced, while acidity increased with higher plant density (Gaikwad *et al*, 1981). Yadav *et al*, (1981) observed that the volume, spread and number of branches per tree decreased with increasing plant density, while the height of plant increased with the increase in plant density. Mitra (1983) recorded increased yield of L-49 guava per unit area by increasing the plant density, but the number of fruits and yield per plant were considerably reduced. The size of fruits was also reduced due to high plant density. The low plant population showed greater spread of the crown, while higher plant density caused taller plants having erect branches.

Irrigation

Guava plants hardly require any irrigation during rainy season. In the early stage, plants require 8 to 10 irrigations a year, while full grown bearing trees require watering during April to June at bi-weekly intervals to secure higher fruit-set and reduced fruit drop. Irrigation during winter was also found to be effective in reducing fruit drop and improving fruit size of winter crop. In actual practice, however, irrigation is rarely done (Singh, 1969).

Manuring and fertilisation

The results of the experiments on the effect of manures and fertilisers on the yield of guava clearly indicate that guava is very responsive to the application of inorganic fertilisers along with organic manures. The necessity of manuring guava trees for increasing the fruit production was emphasised by Naik (1949) and Hayes (1957), because the fruits are borne on current season's growth and manuring encourages vegetative growth and fruiting. Rangacharalu (1954) reported that application of 1·36 kg of nitrogen per tree produced high yield. A balance supply of NPK to guava plants showed normal growth whereas the plants under nitrogen deficiency exhibited stunted growth with purple patches on the leaf (Mallick and Singh, 1960). Shankar (1966) : Singh and Krishnamurthy (1967) and Singh and Singh (1970) reported that fertilisation of guava not only increased the yield but also improved the quality.

The beneficial effect of nitrogen nutrition on growth and fruiting of guava was reported by Tiwari *et al*, (1968). They observed that application of nitrogen stimulated growth, increased flower number and fruit yield. The role of phosphorus on yield attributes of guava was, however, not consistent (Rajput and Singh, 1976). Mitra (1983) suggested to apply 260 gm N, 320 gm P_2O_5 and 260 gm K_2O per plant per year in two equally split doses once in the month of January and another in the month of August in the alluvial plains of West Bengal. Azhakiamanavalan and Khader (1981) recorded the maximum yield in trees receiving 1·0 kg each of N, P and K in Tamil Nadu. Chonkar and

Singh (1981) reported that spraying of 3 per cent urea along with calcium phosphate and muriate of potash each at 1 per cent significantly increased the yield of guava.

Micro-nutrients

Guava sometimes suffers from deficiency of zinc. The usual symptoms of zinc deficiency are interveinal chlorosis, sparsity of foliage, reduced leaf size and fruit production. Spraying the trees with 1 lb (0·45 kg) zinc sulphate and 0·7 lb (0·34 kg) slaked lime dissolved in 16 gallons (60·8 lb) of water cures this condition (Singh, 1969). Pre-flowering spray with 0·4 per cent boric acid and 0·3 per cent zinc sulphate increased the yield and fruit size (Rajput and Chand, 1976). Spraying of copper sulphate at 0·2 to 0·4 per cent also proved effective in increasing the growth and yield of guava (Arora and Singh, 1971).

Intercropping

In the early stages of establishment of guava orchard till the bearing, the interspace can be economically utilised by growing suitable intercrops. In a crop combination involving several plantation crops, vegetables and leguminous crops like, cocao, pineapple, peas, cowpea, gram, beans are considered as safe intercrops. However, when the trees are full grown, intercropping is neither feasible nor desirable.

Training and pruning

Training of guava trees has been found to improve yield and fruit quality. This has been proved by the works done at the Government Fruit Research Station, Basti (Jahuri and Singh, 1973). The main objective of training guava plants is to provide a strong framework and scaffold of branches suitable for bearing a heavy remunerative crop without damaging the branches. The system of training followed by them was open centre, in which the plants were headed back and four primary shoots were retained for intial framework which were subsequently pruned by cutting one-third to half of their length after 3 months. After making the initial framework, the two side shoots were permitted to grow initially and after 3 to 4 years subsequent doubling of selected branches was continued.

The other system was delayed open centre, in which two tiers of framework were prepared and the centre was kept open at a height of 140 cm. Four side shoots were retained in this system also for initial framework, but only one-third of their growth was pruned. For obtaining the second tier, bud growing just below the cut of the central leader was retained. It was observed that training reduced the tree area up to 11·1 per cent in open centre and 27·6 per cent in delayed open centre. This gave an opportunity to increase the number of plants and subsequently the yield per unit area in the ratio of reduction in tree growth.

In Bombay, the system of training guava plants is somewhat peculiar. The branches are bent downwards and tied to each other. The dormant buds are forced to grow and thereby the yield is increased. The method was not encouraged, because the initial increase of yield was found to reduce considerably in the second year (Gadgil and Gadgil, 1933). In Kodur, the trees trained as cordons proved attractive and yielded good crops (Naik, 1949).

As the flowers and fruits are borne on current season's growth, a light annual pruning is considered necessary to encourage new shoots after the harvest. All dead, diseased, crowded growths and suckers coming up from the base and sides of the framework should be pruned back annually.

9.7 Flowering and Fruit-set

Flowering

In Punjab and other parts of northern India guava flowers twice a year, first in April-May for rainy season crop and then in August-September for winter season crop (Gupta and Nijjar, 1978). In Bombay and Madras, there is a third crop, with flowers appearing in October (Hayes, 1970). In West Bengal, two important seasons of blooming was found by Mitra (1983), once in April-May and again in September-October.

The guava bears flowers, solitary or in cymes of two or three flowers, on the current season's growth in the axils of the leaves. Normally, the bearing twigs grow a few centimetres long, putting forth four to five pairs of leaves. Meanwhile, if the flower happens to set, terminal bud ceases to grow till the next growing season (Dasrathy, 1951). Gardener *et al.* (1952) reported that the flowering bud is a mixed type, and the flowering shoot bears the flowers laterally. Both terminal as well as lateral flower bearing shoots were observed by Sehgal and Singh (1967). It was further observed that axillary buds are not produced all over the shoot and may appear scattered (Srivastava, 1962). The flowering or blooming period varies from 25 to 45 days depending on the variety, season and region of growing.

Regulation of flowering

The fruits produced in the rainy season are rather insipid and watery, and do not keep well. In Uttar Pradesh, the winter crop is the one ordinarily desired, as it is not only larger in size, but of much better quality. Smith (1934) stated that the total quantity of fruits borne in a year is greater if only the winter crop is taken. In the Deccan, where the climate is mild, it has been a popular practice to obtain flowering in a desired season. The practice is popularly known as 'bahar' treatment and it is achieved by root exposure and root pruning or exposure to hot

sun before the onset of monsoon. Root pruning, however has a harmful effect on the longevity of trees. In order to have a good winter harvest, deblossoming of rainy season crop and root pruning have been suggested even in Uttar Pradesh where root pruning is not desirable. For obtaining winter crop in Maharashtra, Cheema and others (1954) recommended withholding of water and removing the earth from around the upper roots by June 10, and again covering it with soil and manure mixture. Two light irrigations were also suggested before a normally heavy one, if the rains did not start.

Growth regulators have been found very effective in thinning of flowers and manupulating the cropping season. The effective chemicals so far tried are α-naphthaleneacetic acid (NAA), naphthalene acetamide (NAD), and 2, 4-dichlorophenoxyacetic acid (2, 4-D). Teaotia and Pandey (1970) observed that spraying with NAA at 100 ppm reduced the rainy season crop considerably, but the best result was obtained by hand thinning of summer flowers, which reduced the rainy season crop by 81 per cent and increased the following winter crop by 181·4 per cent. Rathore (1975) reported that NAA at 80 and 100 ppm greatly reduced the fruit-set of guava when sprayed in the month of April. Chundawat *et al.* (1975) observed that NAA at 100, 200 and 400 ppm, when applied to the guava variety Banarasi Surakha for flower thinning, resulted in deblossoming by 25·51 to 82 per cent and recommended it as an alternative for the conventional method of withholding water before flowering. Among the different fruit thinning chemicals used, Kumar and Hoda (1977) suggested NAD at 50 ppm and 2, 4-D at 30 ppm as the most effective chemicals for deblossoming of summer flowers. By deblossoming the summer flowers an increase in yield by 200-300 per cent was obtained and NAD at 50 mg/l was more effective than NAA or 2, 4-D (Mitra *et al*, 1981).

Fruit-set

The initial fruit-set in nature is quite high in case of guava and about 80–86 per cent of the flowers set fruits. But due to severe fruit drop, only 34 to 56 per cent of fruits reach maturity. In varieties like Seedless, the final retention is as low as 6 per cent (Sehgal, 1961). The fruit drop may be due to different physiological and environmental factors. The formation of fruit is first noticed after 12 days from flowering (Dasrathy, 1951). Spraying of GA_3 at 15 or 30 ppm in the month of January proved effective in increasing fruit retention and subsequently the yield (Rajput *et al.* 1977). About 90 per cent fruit retention was also recorded in trees treated with GA_3 at 200 ppm (Sundarajan, 1967).

9.8 Fruit Growth and Parthenocarpy

The growth of guava fruits followed a double sigmoid curve, two periods of rapid growth with a period of relatively slow growth in between (Nandi, 1983).

The weight of fruits and fruit size gradually increased at the first phase, then slowed down and finally increased till maturity. The flesh colour of some of the guava varieties changed from white to pink and fruit acidity, TSS, sugar and ascorbic acid content increased very slowly at the initial stages of development, then increased rapidly and reached the maximum value at full ripe stage (Le-Riche, 1952). Mukherjee and Dutta (1967) reported that guava varieties viz., Safeda, Pyriform and L-49 took approximately 137, 110 and 106 to 138 days respectively to reach maturity. The presence of tartaric acid at flower bud stage and citric acid during the later stages of development of fruits in Red Fleshed variety was reported by Doraipandian and Muthukrishnan (1973). All acids were found to be abundant at the initial stage of development in Seedless variety whereas in seeded varieties it was at the latter stages.

Parthenocarpy is not a common feature in guava even in commercially seedless variety (Dasrathy, 1951). However, Balasubrahmanyam and Rangaswami (1959) obtained parthenocarpic fruit-set in the variety Allahabad Round by self-pollination which they ascribed to be due to the stimulation provided by pollen hormones. In parthenocarpic guava indole-like compounds were isolated by Rangaswami and Kaliperumal (1960). Application of GA_3 at 1000 to 8000 ppm in lanolin paste was found to be effective in inducing parthenocarpic fruits (Rao and Rao, 1960 ; Teaotia *et al*, 1961). Parthenocarpic fruits produced by treatment with GA_3 were oblong in shape and showed 6 to 8 prominent ridges on the fruit surface. The fruits were richer in ascorbic acid content (Rao and Rao, 1960). The seedless nature of Seedless variety of guava was believed to be due to autoploidy and not as a result of parthenocarpic fruit development (Dasrathy, 1951).

9.9 Pests and Diseases

Pests

Fruit fly (*Chaetodacus* spp.) : During the monsoon, the adults lay eggs on the surface of the fruit. On hatching the maggots enter into the fruit and in most cases fruit drop occurs. Spraying of Malathion, Demicron, etc., and burning of the infected fruits minimise the incidence.

Mealy bug (*Cryptolemus* spp.) : The tiny small bugs are found to suck sap from young leaves, twigs and flowers. The affected parts dry up and the yield is considerably reduced. Treatment of soil at the base of the tree with Aldrin, Malathion or Thimet is effective and banding the base of the plant with polythene film will prevent the nymph to climb up from the soil. Nicotine sulphate in water (1 : 600) can be sprayed for control : 0·1 per cent Metacid spray is also effective (Singh, 1980).

Scale insect : The guava scale, (*Pulvinaria psidii*) is one of the serious pests in Bombay. These are green sticky insects found on the leaves, shoots and fruits. Spraying twice with fish oil, rosin soap, 500 gm in 36 litres of water, or with crude oil emulsion, 7·8 kg in 450 litres of water has been suggested to minimise the pest incidence (Cheema and Desmukh, 1927).

Diseases

Amongst the diseases, most damaging to guava are the wilt and anthracnose, other important diseases prevalent in certain regions are stem canker, cercospora leaf spot, seedling blight, etc.

Wilt : This fungal disease is known to occur in Uttar Pradesh, West Bengal, Bihar, Rajasthan and Madhya Pradesh. According to Chattopadhyaya and Bhattacharjee (1968) the disease in West Bengal is caused by *Fusarium solani* and *Macrophomina phaseoli* (*M. phaseolina*), either alone or in combination. In Uttar Pradesh the disease was earlier considered to be incited by *Fusarium* spp. (Das Gupta and Rai, 1947) or *Cephalosporium* spp. (Vestal, 1950). It is characterised by the yellowing of leaves followed by drying of leaves and twigs from the tip and complete wilting of trees within 10 to 15 days. The disease occurs more severely in alkaline soils.

The infection can be effectively minimised by drenching the soil with Brasicol and spraying the plant with Bavistin (0·1%) at an interval of 15 days at the early stage of infection. Jain (1956) suggested to inject the healthy plants with 0·1 per cent 8-quinolinol sulphate. Varieties such as Banarasi, Dholka Sind, Nasik, Supreme are resistant to wilt (Pathak, 1980).

Anthracnose : In the western districts and the terai regions of Uttar Pradesh anthracnose in guava is reported to be a serious disease. The affected plants begin to die-back from the top of the branch, while shoots, leaves and fruits are readily affected. The growing tips gradually turn dark brown and the black necrotic areas extend backward causing die-back (Pathak, 1980). The disease is caused by *Gloeosporium psidii* (*Glomerella psidii*). The disease spreads in cool as well as in hot dry weather.

The disease can be controlled by spraying the trees with copper oxychloride, cuprous oxide, Difolatan or Dithane Z-78.

Stem canker : The infected plants show cracks and lesions on the stem and the affected twigs wilt due to collapse of the stem tissue. The stem canker is caused by *Physalospora psidii*. Pruning of infected shoots and subsequent protection of wound with Blitox or Bordeaux paste are suggested to check the infestation.

Cercospora leaf spot : Water-soaked patches under the leaf caused by *Cercospora sawadae*, are the characteristic symptoms of this disease. The infection can be reduced by spraying lime sulphur (1 : 30) or 0·3 per cent copper oxychloride (Bose and Muller, 1967).

9.10 Harvesting

Seedling guava trees require 4 to 5 years to bear, while grafted, budded or layered plants start bearing at the age of 2 to 3 years. The fruits turn greenish yellow with the advancement of maturity. The guava fruit should be picked immediately when it is mature, because it cannot be retained on the tree in ripe stage and occasionally ripe fruits are liable to be damaged by birds. Individual hand picking at regular intervals is suggested to avoid all possible damage to fruits and plants. Harvesting by shaking the tree is discouraged as the fruits are very delicate at the ripe stage. Mature or half-ripe fruits are mostly liked for consumption.

9.11 Yield

The yield varies in different varieties, and with the care and management of orchard, age of the plant and season of cropping. The average yield per tree is estimated to be 90 kg from the seedling tree and 350 kg from the grafted plants (Singh, 1980). Rao (1946) estimated a yield of 2·2 tonnes per acre, while in West Bengal, Chattopadhyay and Sengupta (1955) estimated fruit yield of 4·5 tonnes per acre. Yield records at Allahabad showed a yield of 55-60 kg from a 3 year-old grafted L-49 guava. In trials with 3 year-old grafted plants of different varieties, Mitra *et al*, (1981) found that all the varieties produced greater yield in the rainy season compared to that obtained in winter (Table 2). The varieties L-49, Allahabad Safeda, and Chittidar were superior in yield to other varieties studied.

TABLE 2. FRUIT YIELD OF DIFFERENT GUAV.

Varieties	Yield per plant (kg)		Yield per plant per year (kg)	Yield/ha (Qntl) (plant density : 278/ha)
	Rainy season	Winter season		
Allahabad Safeda	16·0	12·0	28·0	77·84
Apple Colour	15·2	10·2	25·4	70·61
Banarasi	14·8	10·6	25·4	70·61
Baruipur	16·8	8·7	25·5	70·89
Behat Coconut	13·2	9·3	22·5	62·55
Chittidar	16·2	14·2	30·4	86·51
Harijha	12·8	10·1	22·9	56·63
Lucknow-49	21·1	18·1	39·2	108·98
Pear-shaped	11·3	7·8	19·1	53·09
Red Fleshed	15·0	10·8	25·8	71·72
Seedless	3·2	2·2	5·4	15·01

9.12 Packaging and Marketing

Ripe or mature fruits should be marketed locally as they are liable to be damaged during transportation. For distant markets, fruits should be individually wrapped with polythene bags. Wooden crates or bamboo baskets of various dimensions can be utilised in packaging. In trials at Fruit Research Station, Basti with different packing materials, it was found that perforated polythene wrapping was the best for preventing rotting and weight loss, and for maintaining fruit quality during transportation.

9.13 Storage and Ripening

Being highly perishable in nature, guava fruits should be marketed immediately after hervest. However, the fruits may be stored for a few days, to adjust the market demand. Chundawat *et al*, (1976) reported that all the varieties except Allahabad Safeda could de stored for 2 days at room temperature. The Safeda variety can be stored for 4 weeks in cold storage at 47 57°F (8·5 14°C) (Singh and Mathur, 1954). Singh *et al*. (1976) stored guava successfully up to 6 days in perforated polythene bags and wooden boxes without rotting and much weight loss. Das and Acharya (1969) observed that fruits with 2 or 3 dips in 6 per cent wax or one dip in 9 per cent wax stored well for one month. Mature green fruits were treated with different concentrations of 2, 4-D, 2, 4, 5-T or GA_3 at 100 and 200 ppm or MH at 500 and 1000 ppm. Both ripening and weight loss were accelerated with 2, 4-D and 2, 4, 5-T and retarded by MH and GA_3 treatment (Saha, 1971). Ghosh (1980) reported that fruits of guava variety L-49 could be stored well up to one month at 10°C. At room temperature, fruits treated with Aureofungin and ethylene chlorohydrin plus calcium carbonate, could be stored for 5 days without spoilage and up to 7 days with only 25 per cent spoilage.

9.14 Breeding and Varietal Improvement

In guava growing areas selection of improved individuals has been done by both the growers and the pomologists. Several selected varieties have been identified as better producers or having better quality fruits. Many of these selected plants were subsequently vegetatively propagated for commercial cultivation. One of the outstanding achievement is L-49, a selection from Allahabad Safeda made at Poona.

In India, breeding work for the improvement of guava has been in progress at several fruit research stations. Fifty-five hybrid plants were obtained by crossing

Seedless × Allahabad Safeda. Seedless × Lucknow-49, Allahabad Safeda × Patillo, Apple Colour × Kothrud and Apple Colour × Red Fleshed at the Fruit Research Station, Basti. The performance of the hybrids are being evaluated. Two guava hybrids, 'Safed Jam' and 'Kohir Safeda', were released from the Fruit Research Station, Sangareddy. Safed Jam a cross between Allahabad Safeda and Kohir is a medium-sized tree with drooping branches and fruit set is better than either of the parents. 'Kohir Safeda', a cross between a selected line of Kohir and Allahabad Safeda. The hybrid tree is fairly big in size and dome-shaped and the fruits are bigger than those of the parents. These hybrids are recommended particularly for semi-arid tropical areas like Telangana, Rayalseema. etc. The heterosis in F_1 hybrids of guava has also been reported.

In guava, most of the commercial varieties are diploid ($2n = 22$), while the Seedless variety is triploid in nature and a shy bearer. To evolve a variety with less seeds but more productivity, crosses were made between triploid and diploid at the Indian Agricultural Research Institute by Majumder and Mukherjee (1972). They observed 26 diploid, 9 trisomic and 5 tetrasomic ($2n + 1 + 1$) in 73 plants raised by breeding. The fruits of tetrasomics were normal in shape, size and with less number of seeds (Majumder and Mukherjee, 1972 *a, b*). Interest has been shown in recent years on aneuploidy breeding. The chromosome imbalance thus obtained in aneuploid, imparts certain amount of ovular sterility, which in turn results in reduced seed formation and size. De' Cruz and Babu Rao (1962) first isolated two aneuploids, one with 2i and the other with 30 chromosomes from a progeny of triploid guava. Chauhan (1976) observed that the growth of the plant was adversely affected due to the trisomic condition and the plants were generally less vigorous than diploid. The trisomic, in general, produced smaller fruits with fewer seeds in comparison to diploid varieties. The fruits of tetrasomic plants were smaller with fewer seeds than the trisomics. Some of the tetrasomics are extremely dwarf and can be suitably used as dwarfing rootstocks.

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10

PINEAPPLE

S. K. Sen

The pineapple (*Ananas comosus* (L.) Merr. syn. *Ananus sativus* Schult. f.) is considered as one of the most wanted tropical fruits. The beauty and virtue of this 'Golden Queen' have been extolled by many a poet all over the globe. According to some authors it symbolises balmy tropical lands and leisurely life of tropical areas.

10.1 Composition and Uses

Pineapple fruit is a good source of vitâmins A and B and is rich of vitamin C and calcium. It also contains phosphorus and iron. It contains an enzyme, bromelin and pineapple leaf is a good source of chlorophyll. A pineapple fruit contains—moisture 85·0 per cent ; sugar 13 per cent ; protein 0·6 per cent ; mineral matter 0·05 per cent ; fibre 0·3 per cent ; calcium 0·02 per cent ; phosphorus 0·01 per cent ; iron 0·9 per cent ; acids 0·6 per cent ; vitamin A (carotene per 100 gm) 60 I.U. ; riboflavin (mg per 100 gm) 120 and vitamin C (mg per 100 gm) 63.

Dried waste after juice extraction is a valuable cattle feed. Other by-products are alcohol, calcium citrate, citric acid and vinegar. Preparation of mannosidase, oxalic acid and pineapple gum and pineapple flavour is also possible. The processed products from pineapple are mainly (i) slices in tins, (ii) tit-bits, (iii) juice and squash and (iv) jam and mixed jam. Fruit core is used for preparing candy. The leaves yield 2-3 per cent of strong white silky fibres, 38–90 cm in length which are used for making a fine fabric called pina cloth in the Philippines and Taiwan, these are also used for cordage.

10.2 Origin and Distribution

Bertoni (1919) considered Paraguay as the place of origin of *A. comosus*, but from present information it is difficult to delimit any area so specifically. The

A Kew pineapple

Parana-Paraguay river drainages, suggested as the possible region of origin, was also the home of Tupi-Guarani Indian Tribe. With tribal migration and trades between tribes, the pineapple varieties were distributed throughout most of tropical America and the species developed into a cultigen in the process. The generic name *Ananas* is derived from the Indian 'nana'. Collins (1930) quoted earlier reports and records suggesting the place of origin to be somewhere in the region including central and southern Brazil, northern Argentina and Paraguay namely, an area bounded by 15 to 30° south latitude and 40 to 60° west longitude. The wild Brazilian pineapple (*Ananas microstachys* Lindl) is considered by some to be its ancestor.

Pineapple had spread to the other parts of tropical America by the time of Columbus, who took it to Europe. It reached India in 1548. The important pineapple growing countries of the world are the Hawaiian Islands, Philippines, Malayasia, Thailand, Brazil, Ghana, Kenya, Mexico, Taiwan, South Africa, Australia and Puerto Rico and India.

10.3 Species and Varieties

Species

Pineapple belongs to the order Farinosae and family *Bromeliaceae*. The pineapples are separated from other genera of this family largely on the basis of syncarpous type of fruit which is not found in the rest of the family. Earlier, *Ananas* was considered as a monotypic genus including many varieties but with only one species. Smith (1939) established two genera *Ananas* and *Pseudananas*. In *Pseudananas* syncarp at maturity bears a minute inconspicuous coma of bracts and produces elongated stolons and no slips whereas in *Ananas* syncarp bears conspicuous coma of foliaceous bracts and plants produce slips but never produce stolon. In *Ananas comosus*, syncarp is well over 15 cm long at maturity, floral bracts are relatively inconspicuous and soon exposing the tops of the ovaries and the flesh is palatable. Fruits are normally seedless and the ovules abort and only traces of them can be found in mature fruits. The two genera *Ananas* and *Pseudananas* are having five species and one species, respectively. These are *Ananas bracteatus*, *A. fritzmuelleri*, *A. comosus*, *A. erectifolius*, *A. ananassoides* and *Pseudananas sagenarius*.

Varieties

There is no reliable botanical or horticultural classification of pineapple varieties. Several attempts were, however, made in this direction. Munro (1933) listed 52 varieties grown in England on the basis of flower colour, fruit shape and spine characters of leaves. Only Queen, of his 52 listed varieties, is of any importance now. Hume and Miller (1904) designated the pineapple varieties of

Florida into three groups such as the Queen group with six varieties, Red Spanish with seven varieties and Cayenne with three varieties. Bertoni (1919) published a varietal list with meagre and inadequate descriptions. Jhonson (1935) published a list of 135 varieties, though many of them appeared to be synonyms.

The important commercial varieties include Cayenne with its subvariety Hilo ; Queen with several subvarieties 'Z' Queen, Macgregor, etc. ; Singapore Spanish, Red Spanish, Pernambuco with a few subvarieties : Ananas amarello ; Vermelho and Monte Lirio have spineless leaves. The ten leading countries together with the variety/varieties grown in each country are listed as follows :

Country	*Varieties*
Hawaii	Cayenne and Hilo
Philippines	Cayenne
Malayasia	Singapore Spanish
Australia	Cayenne and Queen
Puerto Rico	Cayenne and Red Spanish
Kenya	Cayenne
Mexico	Cayenne
Cuba	Cayenne and Red Spanish
Taiwan	Cayenne
Brazil	Red Spanish and Abacaxi

The following are the important varieties of pineapple grown in India.

Giant Kew : This is grown extensively and is ideal for canning industry. The plants are vigorous, leaves are long little trough-shaped with straight margin, not serrated. The leaves commonly have short sector of small marginal spines 2 to 5 mm long just behind the tip and again irregularly on the base near its attachment to the stem. The upper surface is dark green with a superficial brownish-red along the entire length confined to the central two to three leaves, lower side ashy grey. It is a late fruiting variety with peak fruiting season in South Bengal from third to fourth week of June and in North Bengal, it is from second to fourth week of July. About 10-15 per cent of fruits ripe in winter. Fruits are of large size with an average weight of 1·9 kg, ranging from 1·6-3·0 kg and up to 4 kg with suitable care in some areas. The shape is cylindrical with slight tapering at the crown, eyes broad and shallow. The colour of the fruit when unripe is dark blackish-green but orange-yellow with some green mottling when ripe. The flesh colour is light yellow, almost fibreless, very juicy with pleasant flavour. Summer ripened fruits have more yellow pigment, higher translucence and are of better taste than winter-harvested fruits. It is a shy suckering variety with 2-3 slips, and 1-2 suckers per plant per year. Crown normally one but occasionally more and typically attached to the fruit without a narrow neck. The aromatic summer harvested fruits were found to have a much

greater volatile oil content, particularly higher amounts of ethyl esters whereas winter fruits contained higher amount of methyl esters.

Queen : This is an outstanding table variety and it has a number of sub-varieties. The variety is not suitable for canning. The plant, fruit and shoots of Queen are smaller than Cayenne. The leaves are spiny with small closely spaced spines and leaf margin serrated. Leaves are greenish-brown in colour. Plants can stand adverse climatic conditions. Fruits size is small with average weight of 1·25 kg and the range varying from 1-2 kg. Fruits are almost cylindrical and the fruitlets are smaller and the centre or nipple is elevated. The prominent and irregular eyes are deep set. Scales cover about a third of the pips and end in a short blunt point. In ripe fruits shell colour is golden yellow and flesh is deep golden yellow, less juicy than Cayenne but with crisp (less fibre) texture, pleasant aroma and flavour. The sugar and acid contents are slightly lower than Cayenne. The fruits ripe uniformly and keep well after reaching ripeness. Crown single and small in size and in this variety slip and sucker formations are many. The peak fruiting season in North Bengal is from second to third week of June and in South Bengal it is about a fortnight earlier.

Mauritius : This is a mid-season variety and the fruits are of medium size. There are two types- yellow and red skinned. Yellow types are oblong, sloping slightly towards apex and the other one is rounded at the base and sloping abruptly towards the crown. The fruits of the yellow type are green in colour when mature and gradually turn deep yellow when ripe. The crown is large and spiny and the flesh is light yellow fibrous and medium sweet. The fruits of red type are red when ripe ; flesh is reddish-yellow, fibrous but sweeter than the yellow type. The crown is medium in size and also spiny, leaves are closely serrated.

Indigenus Types

In Assam there are two indigenous types namely Jhaldhup and Bakhat. Both fall in Queen group. Jhaldhup has sweetness well blended with acidity and has a characteristic alcoholic flavour, Bakhat is markedly sour.

In West Bengal, two indigenous types are grown. Baruipur Local is grown in Baruipur, Sonarpur and Joynagar area of South Bengal. Plants are moderately vigorous, leaf margins are heavily serrated, fruit size ranges from 1-2 kg and conical in shape with single but heavy crown, ripe fruits are reddish yellow ; flesh yellow in colour and fibrous, little stringy and sour in taste and eyes are irregular and deeply set. Plants are of heavy suckering habit and early bearing. The other indigenous type Haricharan Vita is grown in some pockets of Siliguri subdivision of Darjeeling and Sadar subdivision of Cooch Behar districts. The plants are vigorous, hardy and heavy suckering. Fruits are greenish-yellow with one to two crowns per fruit. Flesh is fibrous, sweet but little stringy.

Besides Kew, Giant Kew, Queen and Mauritius, the other important varieties are Singapore Spanish (Ruby), Red Spanish, Pernambuco.

The following important varieties of pineapple namely Mesmerah, P-R-67 Typhone No. 1 and Typhone No. 3 have recently been introduced.

Commercial varieties

The characters of some commercial varieties grown in important pineapple producing countries are summarised hereunder.

Cayenne : This variety is the most widely grown for commercial production and canning in the Philippines, Hawaii, Mexico, Taiwan, Kenya, Australia, South Africa, Guinea and Puerto Rico. The plants are very heterozygous though originating as a single genotype, it now consists of a number of clones which have arisen as somatic mutations. The stem grows to a height of 20-50 cm with 60–80 leaves. Leaves reddish mottling above and silvery grey beneath, smooth margin except near the tip and base where few small spines are present. Fruits are large, 2·5 kg average weight almost cylindrical with greater diameter at base, dark blackish-green when unripe, changing to yellow with green mottling on ripening ; fruitlets fairly flat, about 2·5 cm in diameter each subtended by slightly serrated bract, usually seedless ; juice with 0·5 0·9 per cent acid and 12-16 per cent sugar.

Red Spanish : It is extensively cultivated in the West Indies, Cuba, Puerto Rico and Mexico and is used mainly in the fresh fruit trade. The leaves are long and spiny ; fruits 0·9 to 1·8 kg in weight, rather square ; fruitlets few, large, shell tough and firm, orange-red ; flesh pale yellow, fibrous with pleasant aroma.

Singapore Spanish : This variety is grown in Malaysia for canning industry. Leaves about 50, margins smooth except for a few spines near the tip. Fruits cylindrical, reddish-orange when ripe, 1·6 to 2·3 kg in weight : flesh golden yellow, fibrous, good-flavoured, core small.

Abacaxi : It is widely grown in Brazil for local markets. Plants erect ; leaves with spiny margins ; fruits pyramidal, about 1·5 kg in weight ; fruitlets small ; flesh pale yellow, abundant juice and good flavour. Related varieties are Pernambuco and Sugar Loaf.

10.4 Soil and Climate

Soil

Sandy and loamy soils or laterite soils on hill tops are best for pineapple. It can grow in new alluviums and old alluviums with good drainage. High manganese/ferrous ratio in soil is considered injurious and spray of 1 per cent $FeSO_4$ is recommend on the leaves of the plants under such condition. Fruits are larger on heavier soils and flavour is better when grown in lighter soil. Heavy

clay soil and high water table are not conducive. The optimum pH range for pineapple cultivation is between 5·5 and 6·0.

Climate

Pineapple is essentially a tropical plant but is known to adapt well in subtropical areas also. The fruit grows well near the sea coast as well as in the interior, so long as the temperature range is between 21°C and 23°C. According to Johnson (1935) optimum temperature for pineapple is from 15·5-32·5°C. Very low temperature is harmful but some cool weather in winter improves the quality. Bright sunshine and total shade both are harmful. Pineapple can grow near sea coast as in west coast and also can grow successfully up to 1525 m above sea level. It grows in Golaghat in Assam with annual precipitation of 75 cm and in Khasi hills with annual rainfall of 500 cm. Annual rainfall of 150 cm is considered optimum for pineapple although it can grow in areas having 51 cm to 554 cm of rainfall annually. Areas with strong winds should be avoided as ends of leaves get bruised.

10.5 Area and Production

The total world production of pineapple is about 3·5 million tonnes. Purseglove (1972) mentioned that the largest producers giving the approximate annual production are Hawaii 900,000 tonnes from 30,000 ha of which 99 per cent is used for canning, exporting about 280,000 tonnes of canned pineapple per year, and 40 million gallons of juice ; Thailand 300,000 tonnes ; Brazil 300,000 tonnes ; Malaysia 200,000 tonnes ; Mexico 200,000 tonnes with exports of fresh fruits to the United States ; Taiwan, 200,000 tonnes ; the Philippines 150,000 tonnes ; South Africa, 140,000 tonnes ; Australia 90,000 tonnes. The greater part of pineapple grown commercially are used in the processing industry. Most of the canned products are exported to Europe and North America. Fresh pineapples are exported to Europe from South Africa, Kenya, Cuba, Guinea, East Cameroun, Martinique and Azores. Fruits of very good quality are produced in Azores under glass.

In India the area under pineapple is approximately 25,000 ha. It is grown mostly in Assam, West Bengal, Tripura, Kerala, Goa, Orissa, Karnataka and Meghalaya. In West Bengal, the area under pineapple is about 7000 ha.

10.6 Propagation

Pineapple is easily propagated by vegetative methods. It can be propagated by shoot suckers, ground suckers, slips, crowns, stumps, stem-bits and from splitted crowns. Slips were found to be the best planting materials followed by

side suckers and crowns (Nandy *et al*, 1982). Suckers from main stem bear little earlier than slips, but slips produce larger and uniform fruits (Roy *et al*, 1980). Flowering is delayed by about 70 days in crown and about 350 days in stem-bits as compared to that in slips. Walters (1932), Evans (1952), Wang *et al*, (1958). Nambiar (1955) and Sen *et al*, (1980) reported success in propagating pineapple from stem-bits. Evans (1952) and Dass *et al*, (1977), observed that fruit tops splitted into eight vertical sections could be used as propagating materials. But Sen *et al*, (1980), observed greater success with four splitted crowns. According to Rochelle *et al*, (1967), leaves from crowns and slips could be rooted in moist sand. Success with leaf bud cuttings was also reported (Seow and Wee, 1970). Py (1960) recommended suckers weighing 400-550 gm for planting. Wang, (1966) reported promising results with slips, 330-380 gm in weight. Chadha *et al*, (1974) reported that heavier suckers and medium sized slips of 350-450 gm were the best. But Roy *et al*, (1981) recommended slips of 40-45 cm in length and 450-500 gm in weight. Fresh suckers and slips should be left to dry and should not be stored for more than 14 days (Roy *et al*, 1980). Sucker production in shy suckering varieties can be increased with high dose of nitrogen, more moisture and application of maleic hydrazide (Nandy *et al*, 1982).

Rapid multiplication of pineapple plants has been reported to be possible through tissue culture (Helena Mathews, 1980). Dormant lateral buds excised from crowns and leaves when cultured on Murashige and Skoog's basal medium containing NAA, IBA and kinetin produced multiple shoots.

10.7 Cultivation

Preparation of land and planting

The land should be thoroughly ploughed and pulvarised to a good tilth. It should be properly levelled to avoid water stagnation and adequate drainage channels should also be provided.

Pineapples can be planted in early rains or in early winter and anytime of the year with irrigation. Before planting, the suckers or slips should be sun cured and dry leaf scales at the base should be removed and basal ends dipped in 0·4 per cent Difolatan and 0·05 per cent Ekatox to avoid fungal infection and mealy bugs. Suckers should be planted in 10 cm deep holes, but heart of suckers must not be buried. Planting materials are to be collected from well maintained and high yielding plantations. Planting may be done in single or double rows following triangular or rectangular system.

Planting density

The traditional system of planting pineapple in India, accommodates not more than 15,000 to 20,000 plants per hectare as against 50,000 to 60,000 plants in

the Hawaii and Philippines. Increase in yield per unit area and reduction of cost of production thereof can be possible by adoption of optimum planting density and system of planting. Trials at the Indian Institute of Horticultural Research, Bangalore (Chadha *et al*, 1974) have proved conclusively that dense planting in pineapple results in high yields without affecting the quality or size of fruits. In these trials, the planting density of 63,758 resulted in the yield of 118·8 tonnes of fruits with uniform maturity and cylindrical shape in comparison to a yield of 87 tonnes with 43,036 plants per hectare. Gunjate and Limaye (1979) observed that the total number of slips and suckers produced per hectare were also more at higher plant densities in spite of increased yield. Dass and his co-workers (1978) concluded that a spacing of 25, 60, 90 cm between plants, rows and beds respectively, in a two row planting system having a plant population of 53,333 per hectare, produced the best result. Trials conducted at Bidhan Chandra Krishi Viswavidyalaya indicated that plant density of 64,000 with a spacing of 25 cm × 35 cm × 90 cm in double row system is considered most suitable under North Bengal condition (Roy *et al*, 1980 ; Aich, 1981). Further increase in plant density up to 72,727 per hectare can be profitably used by judicious manuring and irrigation, if necessary and application of growth substance to increase the percentage of flowering.

Besides increased yield, high density planting in pineapple has some other advantages. Overlapping of the basal leaves provides shade and reduces evaporation loss, as well as weed growth. Because of crowding of the plants in high plant density, the vigorously growing leaves tend to twist and grow upright which provide the fruits a natural covering to prevent sun-scald and result in uniformly coloured and lustrous fruits (Chadha *et al*, 1974). Although close planting markedly increased the total yield due to production of large number of fruits per unit area, weight as well as the size of the individual fruit were reduced. The fruits obtained from higher plant population also reduced the total sugar content and increased fruit acidity. Triangular system of planting showed high percentage of flowering and increased yield compared to the rectangular system (Roy *et al*, 1980).

Irrigation

Pineapple is mostly grown as a rainfed crop, but supplementary irrigation helps in production. Research at IIHR revealed that 25 per cent available moisture was as good as 80–100 per cent available moisture in field (Anon, 1977). Therefore, 4–6 irrigations in hot months at 20–25 days' interval ensure good crop. In some pineapple growing countries paper impregnated with asphalt is used as mulch. Polythene mulch and oil mulch can be used to a limited extent.

Manuring and fertilisation

Pineapple removes 123 kg of nitrogen, 33 kg of phosphorus and 308 kg of potash from one hectare of land yielding a crop of 40 tonnes. It, therefore, requires abundant supply of nitrogen and potash. Increased yield and improvement in the quality of pineapple by application of fertilisers have been reported from the pineapple growing areas in the different parts of the world

Krauss (1928), Follett-Smith and Bourne (1936) reported that pineapple plants required higher amounts of nitrogen and potash than phosphorus. Vasconcelos (1952) in Brazil obtained the highest yield with 120 kg N, 60 kg P_2O_5 and 120 kg K_2O per hectare. Chen *et al.* (1957) in Taiwan, suggested the optimum fertiliser dressing with 700 kg of ammonium sulphate, 300 kg of superphosphate and 200 kg of potassium chloride per hectare. Treatment with 560 kg N, 140 kg P_2O_5 and 560 kg K_2O per hectare was found adequate for a plant density of 42,000 per hectare (Su, 1957). He (1969) further suggested that the most economic rate of N ranged from 12 to 18 gm per plant, and 40 per cent of this was required for ratoon crop. According to Srivastava (1969), nitrogen phosphorus and potash should be applied in the ratio of 2 : 1 : 1. The results of the experiments conducted at Bidhan Chandra Krishi Viswavidyalaya indicated that nitrogen at the rate of 12-16 gm, phosphorus at the rate of 2-4 gm and potassium at the rate of 10-12 gm per plant should be the optimum for a plant density of 51,000 per hectare (Khatua *et al*, 1980), while Roy (1983) obtained the highest yield with N, P and K at the rate of 600, 200 and 600 kg per hectare respectively, in plant density of 64,000 and 72,727 per hectare. Foliar application of urea at a concentration of 4 to 5 per cent in dry season and 10 per cent in wet season may be made.

Marchal (1971) explained that the critical level of leaf phosphorus of the 'D' leaves was 0·05 per cent for all stages of growth and phosphorus deficiency affected the utilisation of nitrogen. Tay *et al*, (1969) also concluded that high levels of nitrogen increased the nitrogen content in leaf but decreased the potassium content. According to Godfrey-Sam-Aggrey (1970) the yield of pineapple increased when leaf contained 0·35 to 0·40 per cent N, 0·04 per cent P and 0·44 per cent K at fruit harvest and the ratio of K : P varied between 11·2-11·5 : 1. Khatua *et al*, (1980) obtained the highest yield with 16 gm N, 4 gm P and 16 gm K per plant which indicated a K : P ratio in the leaf at the flowering stage as 20 : 1. The most critical level of leaf during the grand period of growth was 3·2-3·6 per cent (Su, 1965).

Among the different sources of nitrogen, the effectiveness of ammonium sulphate as compared to urea and calcium ammonium nitrate in increasing the yield and size was recorded by Chadha *et al*, (1974) and Subrahmaniam *et al*, (1977). Calcium ammonium nitrate was found to delay the maturity of fruits. Treatment with ammonium sulphate showed a reduction in fruit acidity (Khatua *et al*, 1980).

Cibes and Samuels (1958), revealed that the formation of yellowish spots on the margins of older leaves was caused due to magnesium deficiency. Magnesium was found to be the limiting factor for yield in sandy and strong acid soils. On the basis of yield and quality of pineapple fruit, Martin-Prevel (1961) determined the optimum proportion of three fertiliser K : Mg : Ca at 42·5 : 42·5 : 15·0. Su (1965) reported that the critical values of magnesium were 0·22 per cent in leaf tissue and 60 ppm of exchangeable magnesium in the soil. Ramireż-Silva (1946) observed that zinc proved beneficial to overcome chlorosis. Application of zinc at 2 ppm extended the cropping period and improved fruit quality (Srivastava, 1969). Tay (1974) observed that death of apical region of plant was due to boron deficiency. Soil application of magnesium (0·64 gm/plant), boron (0·24 gm/plant) and iron (0·64 gm/plant) hastened flowering by 8-9 days and an increased yield was obtained with magnesium (1·28 gm/plant) and boron (0·48 gm/plant) (Sen *et al*, 1980).

Application of fertilisers in two split doses, once at the onset of monsoon (May June) and again at the end of rainy season (September October) after the fruits are harvested and slips and suckers are removed, has been found effective to promote growth and yield. Fertilisation is followed by earthening around the stem.

Earthening

Earthening should be done after fertiliser application and after harvesting, otherwise lodging will occur. It also serves the purpose of weeding, particularly between the rows.

Weeding

Weeds pose a serious problem in the cultivation of pineapple, especially during the rainy season and manual weeding accounts to 40 per cent of the total production cost. Chemicals have proved to be effective in controlling weeds in pineapple plantation and in bringing down the cost of weeding considerably. Canon (1960) suggested application of Dalapon before planting to obtain complete weed eradication. Gowing and Leeper (1960) noted that *Cyperus rotundus* and *Oxalis martiana* would be controlled by a number of phenoxyacetic, phenylacetic, benzoic and salicylic acids and other chemicals. Monouron at 2 kg per hectare in 90 litres of water gave very good control of weeds in pineapple plantations (Anon, 1961). Silvy (1962) observed that Simazine and Diuron at the rate of 10 kg per hectare were very much effective against grasses and sedges. Bromacil at the rate of 4 kg per hectare was found to be very effective in controlling *Eragrostis curvula* (Dalldrof, 1974) and *Cyperus rotundus* (Perez, 1977). Velezm and Montes (1974) obtained best results with Bromacil at the rate of 3·2 kg per hectare as pre-emergence and 1·6 kg per hectare as post-emergence treatment. Roy *et al*, (1980) in trials with Diuron, Bromacil and Gramoxone observed that Diuron at the rate of 2 kg and Bromacil at

the rate of 3 kg per hectare when applied at an interval of six months effectively reduced both dicot and monocot weed population and increased the yield by about 18·2 per cent compared to that obtained from unweeded plot.

Aftercare of the ratoon crop

After fruit harvest, desuckering should be done immediately, leaving one sucker on the mother plant. Slips should also be removed. Under no circumstances more than two suckers should be retained. After desuckering plant should be fertilised and earthed up.

10.7 Flowering

A pineapple plant generally flowers after attainment of certain vegetative growth and ripeness-to-flower stage, which is attained 11 12 months after planting and formation of at least 40 leaves. A pineapple plant produces only one fruit during its life time and it is often observed that even after 15 to 18 months of growth under optimal nutritional and environmental conditions only 40 to 50 per cent plants come to flowering. Therefore, for induction of flowering, besides optimal nitrogen and potash nutrition, use of growth regulators is considered necessary. According to Friend and Lydon (1979) pineapple variety Smooth Cayenne is a quantitative shortday-plant and promotion of flowering does not require either diurnal variation in temperature or temperature below 25 °C.

Effect of Chemicals

Through the experiences of the people of the Azores Islands it was first possible to know that unsaturated gases like ethylene and acetylene in the form of smoke cause early flowering in pineapple. The induction of flowering in pineapple with auxin was first reported as early as 1939. Clark and Kerns (1942) were the first to describe the response of pineapple plants to auxinic substances (NAA). Since then a large number of growth substances like NAA, IAA, 2, 4-D and ethylene releasing compounds like β-hydroxyethyl hydrazine, ethylene chlorohydrin, Ethrel, etc., have been tried for flower induction in pineapple. Among the auxinic substances NAA and NAA-based compounds like Planofix, and Celmone have been reported to be very effective in the induction of flowering (Das, 1962 ; Balakrishnan *et al*, 1979 ; Maity and Sambui, 1980).

The effective concentration of NAA varies between 10 and 15 ppm. According to Burg and Burg (1966), the auxin stimulation of pineapple flowering is a consequence of stimulation of ethylene biogenesis for about a week following auxin treatment. The effectiveness of Ethrel in this respect has been reported by Randhawa *et al*, (1970). Ethrel or Ethephon at a concentration of 25 ppm in combination with

urea (2%) and $CaCO_3$ (0·04%) induced more than 90 per cent flowering after 50 days of application (Dass *et al*, 1975). Cent per cent flowering was reported by Aldrich and Nakasone, (1975) by the application of dry calcium carbide power or with water into the core of the plants. The effective concentration varied between 0·5 to 2·0 per cent, the best time of application was from 1 a.m. to 9 a.m. and from 8 p.m. to 12 p.m. According to Mwanle (1982) the vegetative growth in terms of leaf number (at flowering), slip and sucker production (atharvest) increased with the increase in plant age at forcing (10 17 months), but the yield was not affected. TSS increased and fruit acidity decreased with the delay in forcing. Interval between forcing and flowering and forcing and harvesting decreased while that between planting and harvesting increased with late forcing. Flowering and harvesting were irregular and significantly prolonged when forcing was delayed. Das Biswas *et al*, (1982) observed that application of calcium carbide (20 gm/l) and Ethrel (0·25 ml/l) in June caused early induction and appearance of inflorescence. Gradual reduction in percentage of flowering was recorded from June to January application. Ethrel treatment showed maximum concentration of endogenous ethylene and growth inhibitors in shoot apices. Sen *et al*, (1980) reported that planting of slips in July and application of chemicals in the next June resulted in high percentage of flowering. Calcium carbide and Ethrel treatment resulted in higher TSS and total sugar in fruits, more flowering as compared to NAA treatment and less slip formation Fruit weight was more with NAA.

Availability of fruits the year round

There is immense possibility of spreading or staggering of fruit harvest almost throughout the year by (i) using different planting materials, (ii) by planting suckers and slips at regular intervals from July to December and (iii) by applying flower inducing chemicals like Ethephon or Ethrel at a concentration of 0·25 ml/l or calcium carbide at a concentration of 20 gm/l.

Investigations carried out at the Pineapple Research Station of the Bidhan Chandra Krishi Viswavidyalaya at Mohitnagar in Jalpaiguri district of West Bengal during 1976-1980 revealed that in order to harvest fruits throughout the year, slips of pineapple should be planted from July to December and Ethrel (0·25 ml/l) and calcium carbide (20 gm/l) be applied, between 335 and 365 days after planting. Fifty ml of Ethrel or calcium carbide solution should be applied at the core of the plant between 7 and 8 p.m. in the evening. Application of chemicals at an interval of 7 days from April to November can ensure a steady harvest of fruits almost throughout the year. It is also necessary that plants should have at least 45 to 50 leaves for flowering to occur in large percentage, and for obtaining a good yield. Calcium carbide and Ethrel treated plants showed higher percentage of flowering and a better fruit quality. The schedule of planting and flowering by chemicals is given in Table 1 for a round-the-year pineapple harvest under North Bengal conditions (Aich, 1981).

TABLE 1. PLANTING TIME AND CHEMICAL APPLICATION FOR ROUND THE YEAR HARVEST

Planting time	Chemicals	Time of application	Days required for emergence of inflorescence	Time of harvest
15 July	Ethrel 0·25 ml/l	15 June	30	December
	Calcium carbide 20 gm/l			December
15 August	Ethrel 0·25 ml/l	15 July	30	February
	Calcium carbide 20gm/l		30	February
15 September	Ethrel 0·25 ml/l	15 August	37	April
	Calcium carbide 20 gm/l		37	April
15 October	Ethrel 0·25 ml/l	15 September	49	May
	Calcium carbide 20 gm/l		40	May
15 November	Ethrel 0·25 ml/l	15 October	68	July
	Calcium carbide 20 gm/l		68	July
	Ethrel 0·25 ml/l	15 April	22	September
	Calcium carbide 20 gm/l	(ratoon crop and plant crop which did not flower in March)	26	October
	Ethrel 0·25 ml/l	15 May	28	November
	Calcium carbide 20 gm/l	(ratoon crop and plant crop which did not flower in March)	32	December

10.8 Fruit Growth and Development

In an investigation on the growth and development of pineapple fruit and changes in the chemical composition during fruit growth from the 30th to 150th day after emergence of inflorescence, Das Biswas (unpublished) recorded a continuous increase in length, diameter and fruit weight up to 120th day. the rate of increase was less pronounced from the 120 to 150 days (harvest). The rate of increase in fruit weight was, however, maximum between 30 and 90 days. The increase in juice content was more pronounced from 30 to 60 days. Although TSS and total sugar contents showed a rise till harvest, the rate of increase was more between 60 and 120 days. The increase in acidity was also higher at this stage of fruit growth, though it continued to rise up to 150 days.

Effect of growth substances

Experiments at IIHR, Bangalore (Anon. 1977) indicated that application of NAA (200-300 ppm in the form of Planofix) at 2-3 months after fruit set increased

the fruit size by 15 to 20 per cent. Fruit size can also be increased to some extent by partial pinching of crown one month after fruit set. Application of NAA at a concentration of 300 mg per litre of water to the developing fruits 2 months after flowering resulted in maximum fruit size (Kwong and Chiu, 1969). Poignant (1969) recorded an increase in fruit weight, yield and a reduction in total sugar by the application of sodium salt of NAA at 110, 155 and 200 mg per litre on the developing fruits, 12 to 16 weeks after the emergence of inflorescence. Wee (1971) suggested that the best time for spraying the developing pineapple fruits (var. Singapore Spanish) with Planofix was 6 weeks after the emergence of inflorescence. It resulted in increased fruit weight, diameter and acidity and delayed fruit maturity. Roy (1980) also suggested use of NAA (300 mg/l) 45 days after emergence of inflorescence. The treated fruits showed an increase in weight and size, while it caused a reduction in total soluble solid and soluble sugar content. Further application of Ethrel (0·50 ml/l) on the NAA treated fruits at 120 days after flower emergence was found to improve the fruit quality.

10.9 Pests and Diseases and Disorders

Pests

Mealy bug wilt : Mealy bug wilt is a serious malady in pineapple and the Cayenne variety is very susceptible. The cause of wilting of pineapple plants is believed to be either due to toxic secretions of the insects or due to virus introduced into the plant by the feeding of mealy bugs. The symptoms first appear on the roots and the roots cease to grow, then follows collapse and rotting of the tissue. The most prominent symptom is an obvious wilting of the leaves, commencing at the leaf tips, accompanied by reddish yellow colour developing in the wilting areas. The comparatively resistant varieties and species are Red Spanish, Pernambuco, Queen, *A. ananassoides*, and *A. bracteatus*, *Pseudananas sagenarius*.

The plant materials should be collected from unaffected plantations. At the time of planting, the basal brownish leaves of the cured planting materials should be removed. Basal portion of the planting material needs to be dipped in 0·02 to 0·04 per cent methyl parathion (Ekatox) as a prophylactic measure. Thimet 10 G should be applied at an interval of 100-125 days at the rate of 17·5 kg per hectare in affected plantations. Use of border areas of 6-8 beds of pineapples, planted parallel with the field margin having a field roadway between them and the rest of the field, is effective in checking the spread of the disease. In Puerto Rico two natural parasites, *Hambletonia pseudococcina* and *Anagrus cocciduorus* are thought to control mealy bugs to some extent.

Diseases

Soft rot, storage rot and fruit rot: These are caused by *Ceratostomella paradoxa* and have been reported from Assam by Chowdhury (1945). Cut end of the fruit stalk should be treated with 10 per cent solution of benzoic acid in alcohol.

Heart rot or stem rot: The disease is caused by *Phytophthora parasitica*. Poor physical condition of the soil and inadequate drainage are responsible for the spread of this disease. The green leaves turn yellowish-green and tips turn brown. The central whorl of leaves when affected will come out with a gentle pull. The basal portion of the leaves shows signs of rotting and will emit foul odour. Control measures include good drainage, proper selection of healthy planting materials, careful handling and prophylactic treatment of planting material with copper fungicides or with 4 : 4 : 50 Bordeaux mixture. Affected plantations should be sprayed with Difolatan, or Captan.

Leaf spot: Besides heart or stem rot, leaf spot occurs frequently under moist warm climate of the eastern part of the country. Small water soaked areas develop on the leaves and these gradually enlarge with straw coloured halo and the affected portions gradually dry. This disease is also caused by *Phytopthora* sp. Control measures are similar to those in case of heart rot.

Disorders

Sun-scald: Sometimes the peduncle bearing the fruit leans or falls on one side exposing the fruit to direct sunrays. The cells under the skin of exposed surface get damaged. Care should be taken to control lodging or leaning and the fruits should be covered with dry straw or banana leaves or its own leaves during April-May.

Fasciation and multiple crown: Multiple crown may occur due to genetical factors as well as due to soil and environmental reasons, sometimes the fruits get flattened and fasciated. According to Collins (1968) these abnormalities are due to some kind of accident affecting normal control of growth sequence during ontogeny. In fertile virgin soil of warm areas, more abnormal fruits occur as compared to less fertile soil.

10.10 Harvesting

Pineapple generally flowers from February to April and ripens from June to August under North Bengal condition. Off-season fruits are harvested in October and winter season fruit are harvested during December. Harvesting for local markets should be done at the full maturity stage and for distant markets at 75-80 per cent maturity stage. At maturity the lowermost eyelets in the variety Kew show orange-yellow colour and eyes get flattened in the centre and bulge on the sides.

The bracts become loose and turn brown in colour. Studies on optimal harvest maturity of Kew variety of pineapple have shown that fruits harvested between 115 to 130 days after flowering were better suited for canning. Harvesting should be done with a sharp knife severing the fruit stalk with a clean cut and retaining 5-7 cm of the stalk. Great care is necessary in handling the fruit as any mechanical injury on the skin may cause the fruit to rot quickly. Spray of parachlorophenoxyacetic acid 10 days before harvest reduces physiological breakdown during transport and storage. The cut end of the fruit stalk may be dipped in a 10 per cent solution of benzoic acid in alcohol to check attack of fungus.

10.11 Yield

The yield from a plant population of 35,000-40,000 per hectare is about 40-50 tonnes and that from a plant population of 43,000-50,000 per hectare normally varies between 50 and 60 tonnes. Lee (1977) reported an yield of 33 tonnes in a plant density of 23,900/ha and 55 tonnes per hectare at 53,796 plant density. Chadha *et al.* (1974) recorded a yield of 118·8 tonnes with 63,758 plants per hectare in comparison to a yield of 87 tonnes from 43,036 plants per hectare. They concluded that by increasing the plant population up to 63,758 plants per hectare, the yields could be increased nearly six times than that obtained from the conventional methods, without adversely affecting the fruit size and shape. Investigation carried out at Bidhan Chandra Krishi Viswavidyalaya (Roy, 1980, Aich, 1981 and Das Biswas, 1983) with a range of plant population from 27,777 to 72,727 per hectare recorded an yield of 53·5 to 106·9 tonnes per hectare, respectively. The variations in yield under the different plant population recorded in the experiments are presented in Table 2.

TABLE 2. EFFECT OF PLANT DENSITY ON FLOWERING AND YIELD OF PINEAPPLE VAR. KEW.

Plant density	Spacing	Percentage of flowering	Yield per hectare (t)
27,777	45 × 40 × 120 cm	90·8	53·5
35,714	35 × 40 × 120 cm	86·3	61·7
50,378	25 × 40 × 120 cm	79·2	63·7
57,971	30 × 40 × 75 cm	86·3	65·2
59,259	25 × 45 × 90 cm	86·2	81·5
64,000	25 × 35 × 90 cm	84·8	94·5
72,727	25 × 35 × 75 cm	82·4	106·9

In order to obtain a good yield from high density planting, application of fertilisers and treatment with flower-inducing chemicals are considered very important.

10.12 Packaging and Transport

For successful marketing, grading of fruits is done on the basis of size, shape, maturity, freedom from disease, pest and blemishes. Crowns should be trimmed to less than 10 cm and the stalk end trimmed to 5-7 cm. After grading, the next important operation is the packaging of fruits. In Assam, packaging is done by wrapping individual fruits with paddy straw. These are then placed vertically standing on stalk in rows in standard-size containers made either of bamboo pieces nailed together or woven around a framework. The interspaces between the fruits should be filled with straw and a firm lining all around the container is given with straw. Usually 12 fruits in two layers are packed in a case. Wooden crates are better than bamboo baskets but cost more. Subject to proper packing, careful handling and adequate protection against rains, pineapples can remain in pack for seven days without their quality being impaired. Bulk of the fresh fruits are despatched to the markets in India mainly by road transport.

10.13 Storage and Ripening

Storage

Storage studies on pineapple fruits carried out at the Bidhan Chandra Krishi Viswavidyalaya showed that maximum duration of storage with minimum spoilage was obtained by treatment with NAA and GA_3 at 500 ppm and 100 ppm, respectively. The treated fruits could be retained in good marketable condition up to 41 days, while the untreated ones stored well for 12-15 days at room temperature. GA_3 delayed the development of yellow colour while NAA enhanced it. NAA also proved effective in preventing storage rots. Mature and ripe pineapple fruits can be stored for four weeks at 85-90 per cent relative humidity and 11-13°C and 8-9°C, respectively. Experiments carried out at Haryana Agricultural University, Hissar have also indicated possibility of extending the storage life of pineapple fruits with GA_3 and Benlate treatments.

Ripening

Ethrel treatment was found effective to enhance uniform ripening in pineapple. Pre-harvest treatment of mature green pineapple var. Perola with Ethrel at 500-2000 ppm resulted in the development of uniform yellow colour in 8 days (Chunha *et al*, 1980). Crochon *et al*, (1980) also observed uniform and rapid fruit colouration when Ethrel at 5 l/ha was applied 9 days before harvest date. The treated fruits were, however, acidic and lacked in flavour, although its appearance was good.

10.14 Marketing

In 1977–78, India is reported to have exported about 2630 tonnes of pineapple products valued at Rs 9·8 million. The main products of export are canned slices, titbits, juice and jam. Of the four main commercial varieties grown in this country Kew and Giant Kew are better suited for canning, while Queen and Mauritius varieties are good for juice production. Calcutta market consumes about 40 per cent of the exportable surplus after meeting local market demand of West Bengal and the rest is absorbed by Delhi and big cities of Bihar and Uttar Pradesh. Eighty per cent of the pineapple exported to up-country markets are consumed by processing factories. Government processing factories at Matigara (Siliguri), Samchi (Bhutan), Singtom (Sikkim) and few other private factories of this state solely depend on North Bengal market for their requirements.

10.15 Breeding and Varietal Improvement

Studies have indicated the same chromosome number, 2n – 50 and a uniform meiosis for all the species of *Ananas*. *Pseudananas sagenarius* has a haploid number of 50 and diploid number of 100 chromosomes with regular meiosis and is fully self-fertile. While meiosis appears to proceed normally, the gametes produced show some irregularities, producing a few giant sex-cells. The presence of giant germ cells, which undoubtedly contain the diploid chromosome number, sometimes give rise to triploid and more rarely to tetraploid plants. Three naturally occurring triploids were identified. The first one was reported from Ecuador by Heilborn (1921). The variety Cabezona, grown in Florida and the West Indies was found to be triploid (Collins, 1933) and a vigorous growing, unnamed variety collected in Brazil by Baker and Collins in 1939 was triploid. Tetraploids are produced in populations of hybrid diploid plants but much less frequently than are triploids. Tetraploid 1020 appeared to be a varietal amphidiploid. It received a diploid set of chromosomes from Pernambuco and a complete set from Monte Lirio. The other original tetraploid 9267 appeared in a back-cross population produced by crossing an F_1 hybrid plant Cayenne × Ruby, back to Cayenne parent. By crossing tetraploids with various diploids, hybrid tetraploid population can be obtained. Tetraploid plants and diploid-tetraploid chimeras have been reported in Cayenne by treating apical meristem tissues with colchicine (Kerns and Collins, 1947). Collins and Kerns (1946) also reported on the inheritance of three leaf types –spiny tips, characteristic of Cayenne variety : spiny, a character typical of many varieties in which the entire leaf margin bears spines and the type known as piping, a completely spineless leaf form. The spiny tip and spiny characters are the phenotypic expressions of a single pair of alleles, with spiny tip being dominant. The homozygous SS and heterozygous Ss produce

spiny tips. The piping and non-piping characters are controlled by another non-linked pair of alleles with the gene P(piping) being epistatic to S and s. The homozygous PP genotype produces pronounced piping than PP genotype. Frequent mutations of S to s occur and in fields of Cayenne (Smooth Cayenne), a few spiny plants and smooth-spiny chimeras continue to appear but the reverse mutation from spiny to smooth leaf is rare. A large number of mutants have been reported in Cayenne like White flowers, Reduced Flowering Beauty, Flowering Beauty, Collar-of-Slip, Multiple Crown, Paper Leaf, Nubbin, Big Eye, Seedy, etc.

Programme of variety improvement envisages introduction, evaluation and selection of as many of the existing varieties as can be secured. Significant results in this respect have been obtained in Australia, Formosa and South Africa, where progress is being made in improving Cayenne variety and in Malaysia in Singapore Spanish. The first breeding work however, was started by Webber (1905) in Florida. Subsequently in Hawaii, Philippines, Formosa, Brazil and South Africa research work were directed towards obtaining plants which might be better adapted to local conditions or requirements. *Ananas comosus*, with its numerous varieties produces seedless fruits because of self-incompatibility of germ cells. Most of the varieties are cross-fertile. Varieties of *comosus* produce viable F_1 seeds and fertile F_1 plants when crossed with other species of *Ananas*. In genetic hybrid between Cayenne and *pseudananas* only 5-10 per cent of the seeds produced, are viable. In varieties like Pernambuco (resistant to heart and root rot), Queen (good quality and uniform ripening), Singapore Canning or Ruby (good shape), Red Spanish (hardy, vigorous plant, resistant to wilt, heart rot and root rot) and in *Ananas ananassoides* (high sugar and acid, small core, resistant to nematodes, wilt, heart and root rot), *A. bracteatus* (fruit size larger than *ananassoidees*, plant resistant to wilt, heart rot and root rot, core small), *P. sagenarius* (immune to heart rot, root rot, resistant to wilt) are found most of the characters visualised in an ideal variety.

The technique of breeding in pineapples includes cross-pollination by hand in absence of natural cross-pollination. It is unnecessary to emasculate and protect the pistillate plant of a cross, to cover staminate parent or to cover or protect the pistillate parent after pollination. The mature seeds are collected by cutting the fruit into eight to ten longitudinal sections and removing flesh adjacent to core and then by bending the sections. Seeds are dried, kept in fumigant like carbon disulphide for 48 hours and before germination seeds should be treated with concentrated sulphuric acid for 30 to 60 seconds. The seedlings are properly cultured in sterilised sand and then after 30 to 40 days in soil boxes

When the seedlings are about 10 cm high they should be shifted to new flats. They remain in the flat until ready for field planting at 15 to 18 months of age. Before planting in the field, the small, weak and slow growing seedlings are eliminated. The seedlings in the field require 16 to 30 months to reach the mature fruiting stage. The first selections of hybrids possessing some of the

desired characters are made in the variable population at the time of fruit harvest. Selected plants are propagated as clones for future comparative tests.

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11

PAPAYA

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The papaya is an unusually interesting plant producing fruits of many uses. It is easily propagated and grown and produces fruits under tropical condition in less than a year but in northern India in about a year and a half.

11.1 Composition and Uses

The ripe fresh fruits of papaya are eaten throughout the tropics. They are used in preparation of jam, soft drinks, ice-cream flavouring, crystallised fruits and are canned in syrup. The seeds are also used for their medicinal value. Unripe fruits are commonly used as vegetable for cooking. Ochse (1931) reported that young leaves are eaten in Java as vegetables. Papain, prepared from the dried latex of immature fruits, is a proteolitic enzyme similar in action to pepsin and is used in meat tenderising preparations ; manufacture of chewing gum and cosmetics ; as drug for digestive ailments ; in the tanning industry for bating hides ; for degumming natural silk and to give shrink resistance to wool (Purseglove, 1968). Papaya is a very wholesome fruit, and Aykroyd (1951) ranks it second only to mango as a source of the precursor of vitamin A. While this vitamin is generally associated with carotene, the yellow pigment in the papaya is not carotene but caricaxanthin. The composition and food value of ripe papaya fruit are given in Table 1.

TABLE 1. COMPOSITION AND FOOD VALUE OF FRUIT

Moisture	89·6 per cent	Vitamin A	2020 IU/100 gm
Protein	0·5 per cent	Vitamin B_2	0·04 mg/100 gm
Fat	0·1 per cent	Vitamin C	40 mg/100 gm
Carbohydrate	9·5 per cent	Nicotinic acid	0·2 mg/100 gm
Calcium	0·01 per cent	Riboflavin	250 mg/100 gm
Phosphorus	0·01 per cent	Calorific value	40 per 100 gm
Iron	0·4 per cent		

Papaya in bearing

11.2 Origin and Distribution

The papaya (*Carica papaya* L.) is an important fruit of tropical and subtropical regions of the world. It is a native of tropical America (Hofmeyr, 1938) and was introduced to India in the 16th century. It is now grown in all the tropical and subtropical countries like Australia, Hawaii, Taiwan, Peurto Rico, Peru, Florida, Texas, California in the USA, Gold Coast, various parts of Central and South Africa, Pakistan, Bangladesh and India. According to Purseglove (1968), it probably originated in southern Mexico and Costa Rica. It is closely related to *Carica peltata* Hook & Arn, which occurs in this area, and may have arisen by hybridisation. It was taken by the Spanish to Manila in the mid-16th century and reached Malacca shortly afterwards. From there it was brought to India.

11.3 Species and Varieties

Species

Papaya belongs to the family Caricaceae a small, somewhat anomalous family with four genera, of which three are in tropical and subtropical America and one in Africa. The genus *Carica* contains about 40 species but only three are of horticultural importance. Of these *Carica papaya*, the common papaya, is extensively grown in India. *Carica candamarcensis* Hook f., known as mountain papaya, grows to a height of about 2·40 metres, stands lower temperature and thrives well at elevations between 1500 and 2000 metres. The fruit is only 7·5 to 10 cm long and ripens mainly from May to August (Madhava Rao, 1974 b). Swingle (1947) described another species, *Carica monica* grown in the Amazon basin.

Varieties

A large number of so-called papaya varities is found in cultivation. As a matter of fact, none of these is a real variety, since it can not be relied upon to reproduce the parental characters in all the progenies.

Washington : Fruit is round to ovate in shape, medium to large in size, over 20 cm long and 40 cm circumference at its maximum bulge. The weight of fruit is about 1 kg. It is sweet and has desirable flavour.

Honey Dew : The variety is best suited for northern India. The bearing is heavy. Fruits have less number of seeds with good flavour and taste .

Coorg Honey Dew : It is a chance seedling of Honey Dew variety. The plants are mostly hermaphrodite but occasionally pistillate flowers are also observed. The fruits are oblong. It is a dwarf and heavy bearing variety. The flesh is thick with good flavour.

Co. 1 : It is a selection from the progenies of var. Ranchi. Plant dwarf. Fruit round or oval in shape with golden yellow skin and orange coloured flesh.

Co. 2 : This is a pure line selection from a local type. The plant is medium tall in height. Fruits are obovate and large in size ; skin yellowish-green ; flesh orange coloured, soft and moderately juicy. It is a good table fruit and also a high papain-yielding variety.

Co. 3 : This is a hybrid between Co. 2 × Sun Rise Solo, a tall vigorous plant. The fruit is medium-sized, sweet with good keeping quality.

Co. 4 : This was evolved from a cross between Co. 1 × Washington. Plant medium-tall. Fruit large ; flesh thick yellow with purple tinge, taste sweet ; good keeping quality.

The Co. varieties were evolved and released from Tamil Nadu Agricultural University, Coimbatore.

Pusa Delicious (Pusa 1-15) : This is a gynodioecious variety in which two sex forms, i.e., pistillate and hermaphrodite are found. The fruits are medium in size with deep orange flesh colour having excellent flavour.

Pusa Majesty (Pusa 22-3) : This is also a gynodioecious line. The fruits are medium in size and round in shape. The fruit flesh solid in texture and yellowish in colour having good keeping quality and is less prone to the spoilage during transportation and storage. Plants have also tolerance to viral diseases.

Pusa Giant (Pusa 1-45V) : This is a dioecious variety and plant bears fruit at one metre height. The plant can withstand strong winds and storms. Fruits have attractive big size and weight ranging from 2·5 to 3·5 kg per fruit. It can also be used for vegetable and canning industry.

Pusa Dwarf (Pusa 1-45D) : This is also a dioecious variety having dwarf stature and more precocious in bearing. The plants start bearing from 25 to 30 cm above ground level. The fruit size is medium (1 to 2 kg) and oval in shape. This varity is most suitable for high density orcharding, nutrition garden and kitchen garden.

The Pusa varieties were evolved at IARI Regional Station, Pusa, Bihar.

J.E. Higgins was the first to use the name Solo in his reports when referring to the small fruited papayas grown in Hawaii. Over the years, major improvements were made possible in many plant and fruit characteristics. In 1948, Line 5 Solo was introduced and this was replaced by Line 8 Solo and Kapoho Solo. Line 10 Solo, Waimanalo, Higgins and Wilder are also important lines.

Solo : The fruits are pear-shaped and of excellent quality.

Besides the above mentioned varieties, the other important varieties are Peradeniya, Red Fleshed, Phillipines, Madhubindu, Barwani and Ranchi.

The selections made at the G. B. Pant Agricultural University, Pantnagar, viz., Pant Papaya 1, 2 and 3 are recommended for commercial cultivation.

In South Africa, Hortus Gold and Honey Gold are commonly grown.

The plant height and fruit characteristics of some papaya varieties are given in Table 2.

TABLE 2. PLANT HEIGHT AND FRUIT CHARACTERISTICS OF SOME PAPAYA VARIETIES

	Plant height (cm)	Weight of fruit (gm)	No of fruits/tree	Fruit length (cm)	Fruit width (cm)	T.S.S (percentage)	
Washington-1	145	1000	11	16·5	12·6	10·1	Singh and Sirohi (1977)
Washington-2	233	887	68	18·6	10·1	11·0	Singh and Sirohi (1977)
Honey Dew-1	122	1112	14	15·8	13·3	9·8	Singh and Sirohi (1977)
Honey Dew-2	246	1503	27	19·7	13·1	9·2	Singh and Sirohi (1977)
Coorg Honey Dew-1	127	—	20	—	—	—	Singh and Sirohi (1977)
Coorg Honey Dew-2	205	1366	41	16·2	13·3	9·8	Singh and Sirohi (1977)
Co. 1	112	1200–1500	42–45	16·5	15·6	12·5–13·6	Veerannah *et al.* (1982)
Co. 2	120	1000–1500	30–40	—	—	11·5–12·5	Veerannah *et al.* (1982)
Co. 3	medium	885–1000	35–40	—	—	13·8–14·6	Veerannah *et al.* (1982)
Co. 4	250–330	1300–1500	40	—	—	13·2–13·5	Veerannah *et al.* (1982)
Sun Rise Solo	195	250–400	50–60	—	—	13·5–15·0	Veerannah *et al.* (1982)
Solo Hawaii	237	295	48	10·1	7·6	11·8	Singh and Sirohi (1977)
Pusa Delicious (Pusa 1–15)	216	1005	39	—	—	13·0	Mansha Ram (1982)
Pusa Majesty (Pusa 22–3)	196	950	40	—	—	9.0	Mansha Ram (1982)
Pusa Giant (Pusa 1–45V)	220	1910	16	—	—	7·0	Mansha Ram (1982)
Pusa Dwarf (Pusa 1–45D)	130	1020	41	—	—	6·5	Mansha Ram (1982)

11.4 Soil and Climate

Soil

Papaya is an evergreen plant and it bears flowers or fruits for most part of the year and hence it requires a soil of high fertility and good drainage (Shetty, 1953). Adequate drainage and soil aeration are important factors for successful papaya cultivation. Being a shallow rooted plant, the papaya can be grown in soils about 45 cm deep. Under water logged conditions, the foliage turns yellow, the lower leaves drop prematurely and the growth is adversely affected. Prolonged water-logging results in rotting of stem. A well-drained sandy loam soil rich in plant food is the best for papaya cultivation (Singh and Dahiya, 1982).

Climate

Papaya grows well in tropical climate. It requires warm and humid climate and can be cultivated up to an elevation of about 1000 metres (Madhava Rao, 1974 b). Temperature below 10°C retards the process of maturity and ripening of fruits and to a certain extent the growth and setting of fruits (Shetty, 1953). Cheema and Dani (1930) stated that a dry climate characterised by a meagre rainfall tends to add to the sweetness of fruit whereas wet climate with heavy rainfall tends to reduce the sweetness. In northern India, the occurrence of low temperature and frost restricts its cultivation (Singh and Dahiya, 1982). Papaya production is possible in all parts of South India, excepting at elevation exceeding about 1515 m from the sea level and areas subject to frost or frequent cyclonic weather (Naik, 1949). Although, it prefers humid climate, papaya can not stand water stagnation.

11.5 Area and Production

In India, it is now widely grown in almost all the states with tropical and subtropical climates. Though it is successfully grown all over the country, the important papaya growing states are Andhra Pradesh, Tamil Nadu, Assam, Bihar and Maharashtra. Statistics regarding papaya production in India are even less satisfactory than several other fruits, partly because of shorter life of the plantations and the area under cultivation varies appreciably in different years. According to Singh (1979), it occupies nearly 10,000 hectares in the country.

11.6 Propagation

Seed

Papaya is normally propagated by seed. Since it is a cross-pollinated crop, the plants raised from seeds have a mixed inheritance which makes them highly

variable in performance. It is important, therefore, for the grower to secure his seed from a reliable source, where selection and perhaps controlled pollination are done. If such seed is not readily available, the grower should select seeds only form the best plant on the basis of vigour of the plant, size, shape and colour of the ripe fruit, thickness of flesh, quality, yield and optimum spacing of the fruits on the stem, so that the shape of the fruit is not affected by over crowding (Hayes, 1944). Sowing of seeds soon after extraction gives maximum germination. Cheema and Dani (1930) suggested drying of seeds in sun after extraction. They further stated that the viability of the seeds can be retained for months if they are preserved in clean and air tight bottles. Arumugam and Shanmugavelu (1975) reported that papaya seeds treated with thiourea at 100 and 200 ppm gave higher germination. Ghosh (1978) observed germination of papaya seeds treated with GA_3 and other chemicals. Highest percentage of germination was observed in non-chilled seeds treated with GA_3 at 200 ppm, while chilling alone had little beneficial effect on seed germination. Storage of seeds at 10°C was most effective for retention of seed viability. Among the chemicals tested ferulic acid (10^{-3} M) was also effective for retention of seed viability in var. Co. 1 (Ghosh, 1978).

The best time for raising seedlings is the middle of June to the end of October. Cheema and Dani (1930) stated that sowing after this period will not give satisfactory results. In North India, where occurrence of frost is common, seeds are generally sown from February to April (Singh and Dahiya, 1982). Naik (1949) suggested that sowing may be done at any time of the year except during the hottest and the coldest periods and also during heavy rains, but June to November provides the optimum sowing season. In the eastern part of the country, seeds are usually sown in April-May, so that the seedlings are ready for transplanting before the onset of monsoon.

About 500 gm seed is sufficient to raise seedlings for a hectare of land.

Seeds are sown on raised nursery beds at a depth of 1 cm in rows spaced 15 cm apart with 2·5 cm spacing in the row. Watering with a rose-can is done immediately after sowing and thereafter, regularly in the morning or evening except during the rains. Seeds start germinating within 15-20 days.

Seedlings can also be raised in polyethylene bags. Four to five seeds are sown in each bag filled with a mixture of sieved soil, farm yard manure and sand in equal proportions. The seedlings are left to grow in the bags till these are ready for transplanting in the field.

It is also possible to raise a plantation by sowing the seeds directly at the orchard site but this method involves higher seed rate and increased cost.

Seedlings will be ready for transplanting in the main fields when they are about 60 days old.

Cuttings

Papaya can also be propagated by cuttings, but the method is more expensive and laborious, and requires a large number of mother plants ; hence the method is not usually followed. In exceptional cases, where superior types of trees bearing parthenocarpic fruits are met with, it may be of practical use (Shetty, 1953). Cuttings are prepared from the branches with heal which is also not of frequent occurrence. With intermittent mist and bottom heat 80-90 per cent rooting was noted and the rooted cuttings were ready for transplanting in 5 weeks (Allan, 1964).

Tissue culture

A method of vegetative multiplication of papaya *in vitro* by using shoot tips has been reported. Arora and Singh (1978) studied the effects of auxins, kinetin and GA_3 on growth of papaya callus and found that auxin was essential for initiation of callus and its subsequent growth. Although kinetin and GA_3 were not required for callus formation, 0·5 mg/l kinetin should be added to the medium to promote growth. GA_3 up to 1·9 mg/l had also some beneficial effects on proliferation and growth of callus tissue.

Propagation through the intermediary stage of callus was also attempted with explant from plantlets. Callusing was obtained from stem segments, roots and leaf segments (Rajeevan and Pandey, 1982).

11.7 Cultivation

Preparation of pit and Planting

The orchard site for papaya should be well prepared through repeated ploughing and harrowing. Pits of 45×45×45 cm are spaced 1·8×1·8 m apart. After sufficient weathering, the pits are filled with top soil and farm yard manure in 3 : 1 ratio. Cheema and Dani (1939) suggested to fill the pits with surface soil mixed with well rotted farm yard manure at the rate of 80 to 100 lb (36-45 kg), and bone meal at the rate of 3 lb (1·36 kg) per pit. The seedlings raised in polythene bags or in nursery beds are transplanted, preferably in the evening.

In case of dioecious varieties like Co. 1 or Co. 2, four seedlings are transplanted per pit whereas it would be sufficient to plant 2 seedlings per pit in the case of hermaphrodite types like Solo, Coorg Honey Dew, etc.

The best season of planting is the beginning of the monsoon, but transplanting can be continued from June to November. The seedlings should be provided with shade and other optimum growing conditions till they are well established.

Hoeing and weeding

Weeding should be done regularly to keep the field weed free. At the initial stages, earthing up of the plants is necessary. Light diggings are given after every 3 or 4 irrigations to loosen the soil. In the field with grown up plants, the interspace remains covered well with the top growth which helps in checking weeds.

Removal of male plants

This operation is necessary only when dioecious varieties like Co. 1, Co. 2 are cultivated. The male plants serve only as pollinisers and hence it would be adequate to leave one male plant for every 20 female plants. At flowering, all the male plants other than those left for pollination should be removed. Similarly, leaving only one robust female plant in each pit all other female plants are to be removed.

Irrigation

Papaya responds well to better water management. Adequate irrigation helps in rapid fruit development and also to obtain regular fruit yield. The plant is highly sensitive to water-logged condition and hence it is most important to prevent 'wet feet' in papaya irrigation. In well-drained soils, irrigation at shorter intervals during the early crop stages results in good establishment and also encourages better plant development. In general, irrigation to grown up plants is given once in 7-10 days. The ring system of irrigation is better than the bed system, because the ring system prevents irrigation water from coming into direct contact with the stem, thus preventing collar rot (Purohit and Singh, 1978).

The studies conducted at Tamil Nadu Agricultural University, Coimbatore, on water requirement of papaya indicated that irrigations, when given at 60 per cent depletion of soil moisture level, gave higher fruit and papain yields.

Acoording to Awada (1961) proper irrigation and fertiliser application for a particular environment should be practised if maximum productivity is to be achieved. It was observed by him that high moisture level associated with a normal growth rate tended to shift the plants towards the production of commercially desirable Solo fruits. Further, lower moisture levels shifted plants towards sterility and male floral characters, while higher moisture resulted in excessive production of undesirable carpellodic types. Awada *et al*, (1979) studied the effects of drip irrigation at 3, 6, 9, 12 or 15 gal/plant daily on vegetative growth, fruit yield and mineral composition of the petiole in Solo papaya, and recommended that the irrigation rate should be 1·3 times the pan evaporation of water from the previous week. The yield of Solo papaya in terms of number and size of marketable fruits increased with increasing irrigation. It was further

reported that petiole concentrations of Ca, B and Na increased and those of Mg and Cl decreased with increasing irrigation.

In the subtropical hills, papaya is grown as a rainfed crop because these areas receive a well distributed rainfall from both South-West and North-East monsoons.

Manuring and fertilisation

The nutrition of papaya differs from other fruit crops because of its quick growth, continuous fruiting habit and heavy fruit yield. The earliest known fertiliser recommendation is two applications, one at planting and another 6 months later, of a mixture of 800 lb (363·2 kg) of super phosphate, 315 lb (143·01 kg) of sulphate of potash, 250 lb (113·5 kg) of nitrate of soda, 190 lb (86·26 kg) of sulphate of ammonia and 445 lb (202·03 kg) of volcanic ash to be applied at the rate of one pound (454 gm) per tree (Higgins and Holt, 1914). Cheema and Dani (1930) stated that successful papaya crops could be raised with the application of organic manures like farm yard manure, sheep manure, wood ash and bone meal. Similarly, application of organic manures is reported to give good results in papaya cultivation (Mowry, 1930: Pope, 1930: Anon. 1934; Kumar and Abraham, 1943). Agnew (1948) after reviewing the results of several fertiliser experiments reported that quarterly application of 6 : 12 : 6 mixture of NPK was beneficial. He also recommended three applications per year of a mixture of 8 : 12 : 6 for different growth stages of the plant (Agnew, 1954). From a trial conducted at the Fruit Research Station, Sabour, Roy (1952) recorded that application of phosphate and potash along with nitrogen, significantly improved the yield. According to Hamilton (1954), the fertiliser doses in Hawaii are 0·5 lb (0·22 kg) of 8 : 8 : 8 mixture per plant soon after planting, 1 lb (0·45 kg) of 8 : 8 : 8 mixture per plant 4 months later and 1 lb (0·45 kg) of 4 : 8 : 12 mixture per plant another 4 months later. Chandler (1958) stated that papaya responds to an exceptionally high continuous nitrogen supply which should be at a level higher than for other fruit plants. Jacob and Uexkull (1958) recommended specific doses of N, P and K for different age groups of plants. Kebby (1960) identified that the critical stages for adequate supplies of plant food to papaya are the early growing, blossoming and fruit setting periods and recommended the application of a 8 : 12 : 6 mixture. Tripathy (1961) reported that in a fertiliser trial at Saharanpur, significant increase in plant girth was noticed with N at 0·6 lb (0·26 kg) per plant per year. Ochse *et al.* (1961) opined that the productiveness of a papaya plant was dependent upon its constant growth for which higher rate of fertilisers and organic matter should be applied at frequent intervals. An application of 0·1 kg of 4 : 8 : 5 fertiliser mixture to each plant at fortnightly intervals for the first six months and 0·2 kg thereafter resulted in excellent yields in southern Florida. DeGeus (1967) reported that in view of its fast growing character, papaya responded to a continuous supply of nitrogen to ensure good growth and high fruit

yields. Rajput and Sharma (1970) indicated that the application of nutrients to papaya should be 50 per cent as organic manures and 50 per cent as inorganic fertilisers.

Awada and Suehisa (1975) found that the quantity of nutrients removed was in the descending order of K, N, Ca, Mg and P. Nutrient uptake studies conducted at Tamil Nadu Agricultural University, Coimbatore, showed that the uptake of N, P, K, Ca and Mg was more between flowering and harvesting stages, but the uptake was specifically higher between fruit development and harvest stages. From the results of the experiments on fertilisation at Coimbatore, it was concluded that application of 200 gm each of N, P and K per plant (var. Co.1) in addition to 25 kg of farm yard manure in split doses during the first, third, fifth and seventh month after planting resulted in higher fruit yields. In an another fertiliser trial with Co. 2 papaya, it was noted that application of 250 gm of N per plant per year in six split doses at bimonthly intervals commencing from the second month after planting was optimum for a good yield of fruits and papain. Experiments conducted at the Indian Institute of Horticultural Research, Bangalore showed that 240 gm N, 500 gm P and 500 gm K per plant per year gave the best result for Coorg Honey Dew variety. Satyanarayana Rao (1971) reported that while phosphorus reduced the acidity, potassium increased the TSS, total sugars and ascorbic acid content of the fruit.

Awada and Long (1971) identified the recently matured petiole as the index tissue for analysis of N, P and K in papaya. The maximum fruit yield was recorded in Solo papaya at 1·45 per cent N in the petiole (critical level) and it was suggested that this can serve as a basis for N fertilisation to fruiting papaya plants (Awada, 1969 ; Awada and Long, 1971 a). It was also reported by them that the soluble solids content of fruits was not lowered, nor fruit size was reduced under high N fertilisation. Further, they observed that the concentration of petiole N and fruit yield increased with N application, particularly when N was applied in the form of ammonium sulphate nitrate at the rate of 0·25 lb (0·11 kg) N per plant at six week intervals to 10 months old or older plant. It was found by Awada and Long (1971 a) that the level of K in recently matured petiole was 3·61 per cent when the yield was maximum and recommended that this may serve as the tentative standard for fertilisation. Potassium fertilisation also brought about improvement in some fruit quality characteristics like TSS. Subsequently, Awada and Long (1980) reported that the maximum yield of marketable fruits was associated with petiole concentration of 1·44 per cent N and 2·52 per cent K. The N fertilisation increased the petiole concentrations of N, Fe, Mn, Cu and Zn and decreased the levels of P and B whereas K fertilisation increased the petiole concentrations of K and Mn and decreased those of N, P, Ca, Mg, Na and B.

Regarding P fertilisation of papaya, Awada and Long (1969) reported that 0·25 per cent P in the recently matured petiole was the critical level and this

would tentatively serve as a basis for P fertilisation. It was reported by Awada and Long (1969) that P fertilisation raised the concentrations of P, N, Mn and Zn and lowered those of Cu and K. In a subsequent study, the critical petiole P level for optimal fruit yield of papaya was found to be 0·186 per cent (Awada and Long, 1977). Papaya exhibited tremendous growth and fruit yield responses to P fertilisation at a rate of 202 lb (90·9 kg)/acre applied in two split doses, 102 lb (45·9 kg) during the vegetative stage and 100 lb (45 kg) from flowering through bearing. It was recommended by Awada and Long (1978) that 14 per cent of total P should be applied during the vegetative stage (11 weeks), 54 per cent during the vegetative and bud stages (12 weeks) and 32 per cent during the flowering and fruiting stages (52 weeks) and this rate corresponded to 0·16 per cent P in terms of its petiole concentration, which was slightly below the adequate range of 0·17-0·20 per cent.

An experiment with Co. 2 papaya was conducted in Orissa by Das and Sahu (1981). It was reported by them that as the plant was advancing in age, the N and P contents of the leaf showed a decreasing trend, while the leaf K content increased as the plants entered the fruit development stage. In another nutritional trial conducted at Karnataka, Sulladmath *et al*, (1981) found that application of N and P each at the rate of 250 gm/plant/year resulted in the highest yield of 79·9 fruits per plant, weighing 25·76 kg (64·4 t/ha). While K application significantly increased the total soluble solids and skin thickness, seed weight of fruits decreased with increasing levels of N, P and K. Biswas *et al*, (1981) reported that the maximum fruit yield in Ranchi papaya was obtained in plants fertilised with 250 gm N and 600 gm K and the highest yield was about 250 per cent more than that recorded in the untreated plants.

In an experiment on the nutrition of papaya, Cunha and Haag (1981) estimated the removal of major and minor nutrients per tonne of papaya fruits as follows: 1770 gm N, 200 gm P, 2120 gm K, 350 gm Ca, 180 gm Mg, 200 gm S, 989 mg B, 300 mg Cu, 3364 mg Fe, 1847 mg Mn, 8 mg Mo, and 1385 mg Zn.

Intercropping

During the pre-bearing age, short duration vegetables like cabbage, cauliflower, onion, chillies, radish, tomatoes, etc., can be grown as intercrops which not only keep the soil free from weeds but also add to the income of the growers (Singh and Dahiya, 1982). Care should be taken to maintain the intercrops, so that it will not compete with the main crop. When the plants start bearing, no intercrop should be grown. Papaya itself is a popular intercrop with fruit trees. In young mango and litchi plantations, one or two rows of papaya between two rows of trees can be profitably grown. As papaya produces fruits for only 2-3 years, it does not interfere with the main crop.

11.8 Sex Expression

Linnaeus (1753) classified papaya as a dioecious species. Gammie and Patwardhan (1908) recognised several sex types such as dioecious pistillate, dioecious staminate, andromonoecious, polygamous, staminate and hermaphrodite flowers. Higgins and Holt (1914) recorded 13 sex forms of flowers, while Pope (1930) and Cheema and Dani (1930) recognised 3 and 11 different sex forms, respectively. Storey (1937) reported four types of flower in papaya and classified them as typical female or pistillate, typical male or staminate, hermaphrodite and intermediate. Hofmeyr (1938) in his work on papaya reported 9 different sex forms as female, male, elongata sterile, hermaphrodite, coenomonoecious, pentandria, coexistence of elongata and pentandria, pistillate and hermaphrodite and pistillate and staminate flowers on the same plant. Agnew (1948) described three main types of flowers namely, pistillate, staminate and hermaphrodite or bisexual flowers. Further, he classified hermaphrodite flowers into 3 forms as pentandria, intermediate and elongata according to the nature of their structural modification. Variations in sex was also reported by Sen (1940) and Kumar (1952). Storey (1958) identified 8 working categories later as staminate, terotological staminate, reduced elongata, elongata, carpelloid elongata, pentandria, carpelloid pentandria and pistillate. According to him *Carica papaya* has 3 basic sex forms, viz., staminate, pistillate and andromonoecious. The pistillate plant is stable, while staminate and andromonoecious plants may be either phenotypically stable or phenotypically ambivalent going through seasonal sex reversals during which they produce varying proportions of staminate, perfect and pistillate flowers.

Effect of growth regulators

Lange (1957) reported that treatment of young seedlings of papaya with 10 and 100 ppm of gibberellic acid resulted in increased growth and fresh weight. Sprays of 2, 3-dichloroisobutyrate on hermaphrodite forms of dwarf papaya and Solo increased the number of female flowers (Lange, 1961). Spraying of benzothiazole 2-oxyacetate produced flowers earlier at a lower node and higher yields than the control (Dedolph, 1962). Chacko and Singh (1967) reported that soaking papaya seeds in GA_3 solution accelerated germination and increased the height and fresh weight of the stem. GA_3 spray at 50 ppm increased the femaleness in Co. 1 papaya (Padmanabhan, 1970). According to him, the onset of flowering was hastened significantly by the application of MH and SADH, and the fruits appeared at a lower node and height than in the control. Further, it was reported by him that SADH treatment proved very effective in Co. 1 papaya for the control of height, acceleration of flowering and fruiting at lower node, increase in fruitset and yield. According to Alagiamanavalan (1971), Alar at 500 ppm produced

the maximum number of flowers and fruitset. He further reported that sprays with GA_3 at 50 ppm, Alar at 250 ppm and Phosfon-D at 250 ppm increased the femaleness over control in Co. 1 papaya. Similar increase in femaleness was reported by Singh and Jindal (1972) when papaya seedlings were treated with TIBA at 100 ppm. Moreover, TIBA at 25 ppm induced flowering at lower nodes, but such an effect was not noticed with higher concentrations. Selvaraj (1972) recorded a fruitset of 44·28 and 43·75 per cent with TIBA at 25 and 50 ppm, respectively as compared to 32·40 per cent under control. The quality, yield and size, papain yield, and the proteolytic activity of papain were increased by treat ment with GA_3. Treatment with CCC increased the thickness of pulp and pectin content to an extent of 82 per cent as compared to the untreated plants whereas it reduced the plant growth, delayed flowering and lowered the fruit and papain yields. Application of GA_3 on Coorg Honey Dew increased the production of hermaphrodite and staminate flowers, caused a two-fold increase in ascorbic acid content, but reduced the seed number, fruit size and pectin content (Shanmugavelu *et al*, 1973a). Bhattacharya and Madhava Rao (1982) reported that CCC and TIBA advanced flowering by 9 and 4 days respectively in Co. 2 papaya. In general, the role of growth regulators appears to be worth investigating further.

Influence of environment

Choudhury (1957) stated that sex in papaya is a physiological phenomenon amenable to change by variation in environment. Storey (1958) reported that season had a deciding effect on shift from female sterility to female fertility, the latter being higher in cool nights or short days. The height of fruiting and also sex in papaya have been reported to be altered by environmental changes and growth regulators. (Storey, 1958 ; Lange 1961). Singh *et al*, (1963) found an increase in female sterility during winter months and restoration of female fertility in the same plants during summer. Sex expression has been found to be influenced by planting season (Seemanthini, 1964) indicating the influence of climate on sex differentiation. She observed high percentage of females in Coorg Honey Dew, a hermaphrodite type during January planting than in July planting at Coimbatore, but a similar observation could not be recorded in dioecious type like Co. 1 and Washington. Teaotia and Singh (1967) studied the effect of seasonal variation on sex expression of papaya variety Coorg Honey Dew and reported that the production of female flowers was promoted by long day and high temperature.

Padmanabhan (1970) found that long day treatment, i.e., a photoperiod cycle of 16 hours light and 8 hours dark favoured femaleness in Co. 1 papaya. According to Alagiamanavalan (1971), photoperiodic treatment of 16 hours light and 8 hours dark, given at the early growth stages, caused considerable reduction in seedling height and number of leaves but this trend was reversed, if the

treatment was given at later stages of growth. However, he found out that photoperiodic treatments had no significant influence on the height at which first flower was produced, flower production, and on sex in var. Co. 1.

11.9 Pest and Diseases

Pests

The plant is not affected by any serious pests in India. However, in Hawaii, mites- *Tetranychus* spp : *Tenuipalpus biculatus* and *Hemitarsonemus latus* cause considerable damage to the crop (Purseglove, 1968). Birds also damage the fruits.

Nematodes

The root-knot nematode and reniform nematode cause severe damage to papaya. In the nursery, to control nematodes, granular insecticide should be applied at the rate of 0·6 gm per nursery poly bag. In the main field, 25 gm of Furadan may be applied per plant.

Diseases

Fungal disease

Collar rot : The disease is caused by *Pythium aphanidermatum*, a soil dwelling fungus. At times the disease appears to be serious and causes considerable damage to the crop. Spraying of one per cent Bordeaux mixture or any copper oxychloride at a rate of 2 gm per litre of water will check further spread of this disease. Ensuring good drainage and drenching the plants with any one of the above chemicals prior to the commencement of heavy monsoon will help in controlling this disease effectively.

Root rot : This disease is caused by the fungus *Phytophthora palmivora* Butl., and in the nursery by *Rhizoctonia solani* and *Fusarium* spp. Seed treatment with fungicides like Captan and Cerasan, and sterilisation of the nursery beds by burning with dried leaves, spraying of formaldehyde two weeks before sowing and drenching the soil with copper fungicides will control this disease.

In a screening study conducted by Mosqueda-Vazquez *et al.* (1981) for resistance to root rot caused by *Phytophthora palmivora*, Waimanalo-23, Line 8 Solo, Waimanalo-24, and Line-40 were found resistant, while Line 45-T22 and Kapoho Solo were moderately resistant and Higgins was susceptible.

Viral disease

Papaya mosaic : The occurrence of this disease has been noted from almost all parts of India. The affected plants are stunted in growth, show yellow mottling

and distortion of leaves, bending down of petiole, followed by death of the plant. Diseased plants yield little or no crop. The disease is found to be spread by several species of aphids such as *Myzus persicae*, *Aphis gossypii*, *Aphis malvae*, *Aphis medicaginis*. Careful examination of the papaya plantation and thorough roguing of diseased plants are the most effective methods of minimising the spread of the disease.

Possibility should be explored to evolve a resistant commercial papaya by hybridising *Carica cauliflora* and *C. papaya* (Capoor, 1967).

Papaya leaf curl: The virus disease is characterised by severe curling, crinkling and distortion of leaves accompanied by reduction in leaf size. The disease is transmitted by *Bemisea tabaci*. As the spread of the disease is slow, roguing of affected papaya plants at the early stage of disease development is found effective in keeping the disease in check.

11.10 Harvesting

Mature fruits ripen within a day or so and the colour changes from green to yellowish-green. Ripe fruits may also be harvested from the trees but they are often damaged by birds, so it is advisable to harvest the fruits when mature. When the latex of the fruit becomes almost watery, the fruit is considered ready for harvest (Shetty, 1953). The fruits should be harvested individually with hand taking care to avoid all possible injuries.

The first crop of fruits is harvested in 12-14 months after transplanting. The cropping will be continuous during the life of the plant. In North India, fruits ripen during spring and summer; in hills it is restricted to three to four months from February to May, because it requires a warm climate during ripening. It was also observed that high relative humidity and comparatively high temperature during ripening period may not be conducive to development of attractive colour in fruits which may remain pale green even when ripe (Shetty, 1953).

11.11 Yield

Papaya produces higher yield in the first two years, then declines from the third year. Naik (1949) reported 30 to 150 fruits per tree each weighing 1 to 16 lb (0·45 – 7·2 kg). Cheema and Dani (1930) reported an average yield of 27 fruits per plant, each weighing 2·2 lb (0·99 kg). In Punjab, a crop of 15 to 20 fruits per plant, each weighing 1·5 lb (0·68 kg) was observed by Bajwa and Jawanda (1952). Simmonds (1946) reported an yield of 48 tonnes per acre in Trinidad. Sulladmath *et al.* (1981) recorded an average yield of 79·9 fruits per plant weighing 25·76 kg in variety Solo. In West Bengal, the varietiy Ranchi yielded 40 to 55 fruits, each weighing 1·2 to 3·4 kg (Biswas *et al.* 1981).

11.12 Packaging, Storage and Ripening

After harvesting, the fruits to be consumed locally should be stored in a single layer of straw until they become mellow. For distant transport, it should be packed in bamboo baskets with rice straw to avoid bruising (Madhava Rao, 1974). The most common fungal disease caused by *Colletotrichum gloeosporioides* was found to spoil the fruits during storage and it could be controlled by immersion in hot water (50°C) for 20 minutes (Arriola *et al*, 1976).

Storage

Room temperature (28-32°C) was found to be practically unsuitable for storage of fruits. A temperature of about 20°C was found optimum both for ripening and satisfactory storage. Temperature above this made the fruit susceptible to fungus attack, while at lower temperature the onset of the climacteric was delayed and chilling injury was manifested (Broughton *et al*, 1977). Thiabendazole applied in wax formulation also proved effective to control post harvest diseases of papaya up to 14 days when stored at a temperature of 10°C (Couey and Farias, 1979). Fitzell (1979) observed 37 per cent rotting of fruits after 6 days when the fruits were treated with hot water (55°C), while both hot water and sodium hypochlorite (200 ppm) treatment showed 47 per cent rotting compared to 87 per cent in the untreated control.

Ripening

Fruits of Sun Rise Solo, Kapoho Solo, Line 8 Solo and Waimanalo, when exposed to 2000 ppm of Ethephon solution having a few pellets of sodium hydroxide, ripened within 24 hours as against 96 to 120 hours required for the control (Shanmugavelu *et al*, 1973 b). Besides causing quick ripening, the growth regulator treatment also improved the colour of fruits and quality in terms of TSS, reducing and total sugars, carotenoids and ascorbic acid contents.

11.13 Papain

The immature papaya fruit contains a milky latex. The dried latex called 'papain' is in great demand in the international markets, particularly in UK and USA. Papain has several uses in the industry as an essential ingredient in pharmaceutical, textile and tanning industries. Papain is used in tenderising meat ; for clearing beer ; in the manufacture of cosmetics like snow and face creams and also dental paste ; in degumming silk and rayon ; in the pre-shrinking of wool ; in the tanning of leather and in brewing industry. It has also several

uses in the medical field in the treatment of necrotic tissues, dyspepsia and other digestive ailments, ring worm and round worm infections, skin lesions and ulcers, eczema and other skin diseases and in kidney disorders. Papain is used in detecting stomach and intestinal cancers and also in correcting diphtheria.

Papain production is influenced by several factors :

Fruit size

Fruit size plays an important role in tapping of papain. The yield of papain was reported to be high in oblong fruits (Stockdale, 1927). Singh and Tripathi (1957) found that fruits of 14·3 inches (36·3 cm) in length and 10·9 inches (27·7 cm) in diameter gave the highest papain yield. Seemanthini (1964) stated that the yield of papain was the highest in fruits measuring 1255 to 1544 sq cm in size. She also reported that the yield increased with an increase in the size of fruit and a significant and positive correlation was established between girth of fruit and papain yield in Co. 1 and Selection 7.

According to Irulappan (1980), the fruit size appeared to exert considerable influence on the papain yield since as much area of the fruit surface as possible should be tapped to ensure the maximum yield of papain. A correlation study also revealed that fruit weight, girth, length and breadth were significantly and positively associated with the yield of papain. Among the different types, long fruited ones offered the greatest promise in papain yield as it was seen that the length of fruit had greater influence than circumference.

Fruit maturity

The fruit maturity is another important factor influencing the yield of papain. Sen (1931), Hofmeyr and Roux (1938) and Sanders and Robertson (1944) recorded that unripe but fully grown fruits yielded maximum papain. Jayaweera (1957) also recommended fully grown fruits for tapping. Singh and Tripathi (1957) found 2½ months old fruits to yield the highest quantity of papain. Seemanthini and Balakrishnan (1964) reported that papain yields were more when tapped at 90 days after fruit set. Recent studies conducted at the Central Food Technological Research Institute, Mysore and Tamil Nadu Agricultural University, Coimbatore, also revealed that 90 days old fruit yielded high quantities of papain.

Season

Becker (1950) reported that the flow of latex was low if the temperature was below 10°C. Studies at the Central Food Technological Research Institute, Mysore, showed that the yield of papain was the highest in the month of October. At Saharanpur, the fruits set during July yielded more latex (Singh and Tripathi, 1957). According to Muthuswamy *et al.* (1962), season did not show any marked

effect on latex production at Coimbatore. But Seemanthini and Balakrishnan (1964) reported that papain yields were higher in the months of July to January. Irulappan (1980) found the yield of papain to fluctuate from May to October, among the different types with the lowest yield in September.

Varieties

Marked variations were noted among the different varieties for the yield of papain (Cheema and Dani, 1930 ; Sen, 1931). In Sri Lanka, an improved strain called 'Botanist's Selection' was recommended for the production of papain by Charavanapavan (1952). Muthuswamy *et al.* (1962) recorded higher yields in the varieties, Washington, Philippine, Botanist's Selection, Peradeniya and Co. 1. A Philippine Selection was found to be the most promising by Seemanthini and Balakrishnan (1964), in a study on five inbred selections for papain yield. Khan and Seemanthini (1968) reported that individual plants of some selections made from Peradeniya, Red Fleshed and Philippine types yielded as high as 6 gm of papain per fruit. Foyet (1972) stated that var. Red Panama yielded 21 kg of dry papain per hectare. Madhava Rao (1974 a) reported that the variety Co. 2, evolved from Selection-7, yielded 100-120 kg of papain, per acre, and this is the only recommended variety now in India for papain production. The variety Co. 2 recorded the highest papain yield of 686·59 gm per plant in a period of six months, among the 40 types evaluated (Irulappan, 1980).

Papain extraction

Papaya fruits, which are about 90-100 days old (fully mature but not ripe) are selected for tapping. In the morning, hours before 10·00 a.m., four longitudinal incisions are given on the four sides of the selected fruit from the stalk end to the tip. The depth of the incision should be about 0·3 cm. On incising, the latex starts flowing and this is collected in suitable containers (arecanut spathes, aluminium trays or glass vessels). Care should be taken not to use any other container for papain collection, since it will react with papain rendering it unfit for any use. The latex that solidifies in the cuts should also be scrapped carefully and added to the liquid latex. This process of making four incisions in the untapped fruit surface at 3-4 days interval is repeated thrice or four times over a period of 12 to 16 days. The latex thus collected every time should be dried in the sun or in driers at temperatures ranging between 50 to 55 °C. Potassium metabisulphite (0·05%) is added to the liquid latex in small quantities before it is dried, since this helps to extend the storage life of papain. The drying of papain is continued until it comes off in flakes having a porous structure. The dried papain is powdered, sieved in a 10 mesh sieve and stored in polythene bags or in any other suitable container.

The biochemical analysis of fruits revealed that latex extraction has no effect on the quality of fruis.

Papain yield

Sanyal (1931) reported that a papaya tree would give 8 oz (227 gm) of papain and Sankaram (1942) stated an yield of 1/3 lb (151·3 gm) of crude papain from a tree or 175 lb (79·45 kg) per acre. Sanders and Robertson (1944) estimated 60 to 100 lb (27·24–45·4 kg) per year as the acre yield of papain. Virendrakumar (1952) reported that the yield of papain was about 100 lb (45·4 kg) per acre while Singh and Tripathi (1957) estimated 60 to 75 lb (27·24–34·0 kg) per acre. Muthuswamy *et al*, (1962) found the papain yield to range from 1·23 to 7·45 gm per fruit in 9 varieties, the var. Washington recording the highest mean yield of 7·45 gm per fruit. According to Seemanthini and Balakrishnan (1964), the yield of papain per fruit ranged from 1·70 to 3·71 gm per fruit in 5 varieties. The yield of papain, according to Irulappan (1980), ranged from 1·58 to 5 gm per fruit in a study involving 40 types.

11.14 Breeding and Varietal Improvement

Selection

Due to continuous selection several seedling races are found to produce fairly large proportions of progenies true to the parents from seed and of these Washington of Bombay side and Honey Dew enjoy some popularity in South India (Naik, 1949). Based on the two seasons evaluation of papaya germplasm in Nainital-terai, varieties Barwani Red, Coorg Honey Dew, BR-1, 2, 3, 4 Coimbatore 1B and Washington have been found promising for commercial cultivation. Considerable genetic variability was found in many plants and fruit characteristics like plant height, fruiting height, size, shape, TSS and taste of fruits, number of fruits per tree and weight per fruit. Selection practised from a mixed population of Co. 1 and other resulted into 12 promising selections which were superior than Co. 1 (Singh and Sirohi, 1977). Arising as a chance seedling at the Chettali Orange Research Station, the Coorg Honey Dew papaya has not only spread throughout the length and breadth of Coorg, but is in great demand all over India. Apart from being very delicious, it is a hermaphrodite –a character of economic importance (Ayappa and Nanjappa, 1959). The Solo variety which was introduced from Hawaii at the College of Agriculture, Dharwar, was reported, to be a gynodioecious type of plant. The quality of the fruits was found to be better. The observations in respect to yield and fruit qualily indicated that the variety Solo (line 8) appeared to be the promising. To develop a variety with high papain content, breeding was commenced at the then Agricultural College and

Research Institute, Coimbatore, thirteen selections of papaya introduced from different parts of the world were tested. Considerable variation existed among the different selections in papain yielding capacity, among these, selection 7 consistently yielded the best. Over the years, off-types in this selection were eliminated and the progeny purified by the method of inbreeding until a reasonably pure type was obtained and the same was released as Co. 2 in 1973. Individual fruits of this selection yielded 4 to 6 gm of papain, compared to about 2·25 gm in Sri Lanka (Madhava Rao *et al*, 1974).

Hamilton and Izuno (1965) introduced 'Line 10 Solo' through selection and breeding as a new strain of export papaya. From a breeding programme, in which widely different strains were used as the original parents, a selection was made by Nakasone and his co-workers in 1972, designated as Waimanalo and released as a commercial strain. Nakasone *et al*, (1974) introduced two new Hawaiian papaya lines, viz., Higgins and Wilder having many advantages to the grower.

In South Africa, Hortus Gold type papayas are commonly grown. Allan (1981) reported a new selection of Hortus Gold, viz., Honey Gold which produces attractive golden yellow fruits with high sugar content, pleasant flavour and texture.

Acclimatisation

Heavy or shy bearing is a genetical character in papaya. But some acclimatised varieties give good yield in a specific zone. Variety Ranchi is acclimatised to South Bihar condition and has a wide adaptability under North Indian condition also. Coorg Honey Dew performs well in Karnataka but is a poor yielder in North India. Similarly, Nongpoh and Halflong perform well in north-eastern hill zone, Barwani in central zone, Washington in western zone, and Co. 1 and 2 in a good part of southern zone. Most of these varieties fail to give satisfactory results when grown at other places. Recently, four varieties, Pusa Delicious, Pusa Majesty, Pusa Giant and Pusa Dwarf developed at IARI Regional Station, Pusa, were found to have a wide range of adaptability (Mansha Ram, 1983).

Hybridisation

Hybridisation has been used primarily for establishing species relationship and understanding the genetics of sex in papaya. Its use in evolving new varieties has been limited. Hofmeyr (1936) emphasised the importance of both male and female parents in developing improved varieties of papaya. Several Solo varieties in Hawaii have been developed through hybridisation. Originally, Solo was a polygamous variety which was changed to a gynodioecious variety by the use of several back-crossing to a harmaphrodite source (Storey, 1953).

Breeding programmes were initiated through intervarietal hybridisation between Co. 1 × Coorg Honey Dew and Co. 1 × Washington. The reciprocal combination

were also tried (Desikan, 1972). The progenies were evaluated over a number of generations through sibmating and a hybrid derived CP 60 was identified as a promising selection out of Co. 1 × Washington combination. This is characterised by a purple tinge shade througout the stem, petiole and flowers. The fruit flesh is thick and yellow in colour with a purple tinge. The fruit quality is better than both the parents. The hybrid Co. 1 × Coorg Honey Dew possessed certain desirable characters like weight, volume, diameter and firm flesh of fruit. On the other hand, the hybrid Coorg Honey Dew × Co. 1 exibited low height and earliness of fruiting and star-shaped fruit cavity (Shah and Shanmugavelu, 1973). Interspecific hybridisation was attempted in the genus *Carica*. Studies indicated crossability barriers among many species. The barrier was found to be operating at different stages of development (Subramanyam and Iyer, 1982). With a view to produce harmaphrodite lines, hybridisation was undertaken using Sun Rise Solo as male and Co. 2 as female parents at the Tamil Nadu Agricultural University, Coimbatore. And an improved selection, viz., CP 81 with several special attributes was made. This selection is a hermaphrodite type with an attractive red coloured flesh. The fruit is bigger than Sun Rise Solo and superior in quality to Co. 2. Simultaneously, breeding work among commercial important dioecious varieties was also taken up to obtain new hybrids with distinct morphological and economical attributes. The hybrids were evaluated and have now been released as Co. 3 and Co. 4 papaya. The fruits of Co. 3 (Co. 2 × Sun Rise Solo) possess better fruit size with excellent quality of Sun Rise Solo, while the fruit quality of Co. 4 (Co.1 × Washington) is better than Co. 1 and Washington (Veerannah *et al*, 1982). *Carica candamarcensis* and *C. pentagona* are said to be cold resistant, while *C. cauliflora* is known to be resistant to viruses. The crosses between the *C. papaya* and *C. cauliflora* do not form mature seed but immature embryos can be germinated and grown by employing tissue culture technique, (Mansha Ram, 1982).

Heterosis

Studies were also made to assess the extent of heterosis, if any, in inter-varietal hybrids in papaya. It was observed that significant heterosis was prevalent for all the vegetative characters as well as yield and its components. Heterosis up to 111 per cent over parents for yield was obtained in certain combinations. From a practical point of view with regard to the absolute values in yield, it is was found the combination Thailand × Washington was the best, followed by Coorg Honey Dew × Thailand ; Pink Flesh Sweet × Thailand and Thailand × Solo Yellow Sweet. The yield improvement could be attributed to heterotic effects in major yield components (Iyer and Subramanyam, 1981). It is possible that inbreeding may lead to inbreeding depression which can be restored by the intercrossing of two or more inbreds. Inbreeding Solo strains did not exhibit any loss of vigour as

is the case in many cross pollinated crops. On the contrary, the inbred strains produced more vigorus plants than the commercial strains (Hamilton, 1954a).

Polyploidy and mutation breeding

Several workers have been successful in inducing polyploidy in papaya (Hofmeyr, 1945 ; Singh, 1953 ; Zerpa, 1957). Tetraploids were found to be better than diploids in many horticultural characteristics. But so far no commercial variety has been developed through polyploidy breeding. Similarly, mutation breeding has not resulted into any improved variety of papaya. At IARI, Regional Station, Pusa, a dwarf compact mutant was selected in M3 generation from Pusa 1-15 seeds treated with 15 kR. Repeated full sibmating among the progenies of this dwarf mutant helped in establishing a homozygous population of dwarf papaya in M6 generation. Though per plant yield in mutant is less, the mutant has the benefit of withstanding heavy wind and more plants can be accommodated per unit area (Mansha Ram *et al*, 1981).

Genetical factors of sex expression

Sex in papaya is determined by three genetic factor : M_1 is dominant for maleness, M_2 is dominant for hermaphroditism and m is recessive for femaleness. Each ovoule or pollen grain being haploid can carry only one of these factors. The diploid zygote carrying two sex dominant factors can not thrive, thus the combinations M_1M_1, M_2M_2 and M_1M_2 are eliminated. Of the remaining ones M_1m are male plants, M_2m hermaphrodites and mm females. If a female is crossed with a male ($mm \times M_1m$), $mm + M_1m$ is obtained, half the seeds will produce female plants, half male plants. If hermaphrodites are selfed or crossed the ratio of female : hermaphrodite is 1 : 2. When a hermaphrodite is crossed with a male the ratio of female : hermaphrodite : male is 1 : 1 : 1. (Samson, 1980).

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A palm in bearing

Palm affected by rhinoceros beetle

Palm showing boron deficiency

Palm affected by Tanzore wil

12

COCONUT

T. THANGARAJ and S. MUTHUSWAMI

The coconut palm, *Cocos nucifera* Linn., with its tall, slender and uniformly thick stem and massive crown with large number of leaves, bearing bunches of nuts in their axils, is one of the most beautiful and useful trees in the world. Grown in more than 80 countries of the tropics, it is the most important of all cultivated palms. The importance of the palm lies in the fact that not only does it supply food, drink and shelter, but also provides raw materials for a number of industries intimately connected with domestic as well as economic life. It is pertinent to mention that all the parts of this wonder palm are useful to mankind in one way or other. On account of this, the palm has been regarded as *Kalpa Vriksha* (Tree of Heaven).

12.1 Composition and Uses

Coconut water : It is a liquid endosperm of the tender coconut and is used as a refreshing and agreeable drink and as a useful substitute for saline glucose in intravenous infusions. It is also prescribed in serious cases of diarrhoea and vomiting, against dehydration of the body tissues. It increases blood circulation in the kidneys and causes profuse diuresis. As an urinary antiseptic it eliminates poisons through the kidneys in cases of mineral poisoning. It has caloric value of 17·4 per 100 gm water (Shivanandiah, 1970). The composition of coconut water is as follows : water 95·5 per cent, protein 0·1 per cent, fat 0·1 per cent, mineral 0·4 per cent, carbohydrate 4 per cent, calcium 0·02 per cent, phosphorus 0·01 per cent, iron 0·5 mg/100 gm.

The wet meat or kernel : The kernel or endosperm of the ripe coconut is an important article of food being used in culinary purposes in various forms in all the coconut growing countries. The milk or cream obtained by squeezing the grated kernel diluted with water is used in many preparations and serves as a

base for the preparation of various delicacies of commercial importance. The fresh kernel includes moisture 45 per cent, protein 4 per cent, fat 37 per cent, minerals 4 per cent and carbohydrate 10 per cent.

Desiccated coconut : It is the dried out disintegrated coconut meat and is a very important commercial product having demand all over the world in the confectionary and other food industries.

Coconut flour : Partially defatted edible coconut gratings is an excellent product and is used in bakery and confectionery preparations and also in nutrition feeding programmes in schools.

Edible copra : It is the dried kernel and is available in two different forms, ball copra and cup copra. The whole dry kernel is called ball copra and when it is splitted in two halves in the form of a cup is known as cup copra. The edible copra is soft, sweet and oily and is cream-coloured. It fetches a higher price than the milling copra.

Toddy and toddy products : A sugar containing juice which is obtained by tapping the unopened spadix of the coconut palm is known as toddy. From this vinegar, jaggery, sugar and arrack (alcohol) are prepared.

Coconut oil and oil cake : The dried copra on crushing produces 60-67 per cent oil and 33-40 per cent oil cake. The coconut oil is in great demand for edible purposes, for soap making, toilet and toilet preparations and to a less extent as an illuminant or lubricant. The oil cake is largely used to feed cattle and poultry and occasionally as food by the poor people.

Coir or coconut fibre : It is also an important commercial product obtained from the husk of the coconut. The fibre, after cleaning is dried in the sun and spun into coir yarn either by hand or by using machine. The yarn is then used as such or made into ropes, mats, mattings, nets, bags, etc.

Industries based on coir have developed in many coconut producing countries, especially in India and Sri Lanka. In India, coir manufacture is a traditional industry and has taken deep roots in the economic structure of the rural areas. The industry employs over half a million people and earns a substantial amount of foreign exchange. The world production of coir fibre is estimated to be 0·282 million tonnes, of which India contributes about 50 per cent. Though the annual production of coir in India is 0·14 million tonnes, only one-third of the total quantity is available for export, the rest being absorbed in the domestic market. The coir pith or coir dust which constitute as much as 70 per cent of the husk may be used as manure or soil conditioner.

Miscellneous uses

The endocarp of the coconut, commonly known as coconut shell, is another important part of the fruit. The shell is mainly used for fuel and to a lesser extent for the manufacture of hookah shells, various household utensils, curios,

fancy items, souvenirs, etc. With expanding market demand, the coconut shell is also used for making shell-charcoal, activated carbon, shell-flour, etc. The shell-charcoal is already in demand in the world markets and Sri Lanka meets 90 per cent of the demand.

Besides, the stem of the palm is used for construction of houses and leaves are used for thatching, fencing, making baskets and broomsticks. The petioles, bunch stalks, spathes, stipules, etc., are used as fuels. The decoction of the roots is astringent and is used as mouth wash and gargle. The roots also are roasted, ground and used as dentifrice. In fact, there is no part in coconut palm which is not useful to mankind (Thampan, 1982).

12.2 Origin and Distribution

The intricate problem of determining the home of the coconut has been discussed by a host of workers. A perusal of their contributions revealed the fact that the original home of coconut still remains enshrouded in mystery. However, the available evidences in respect of origin of coconut show that the home of coconut might have been somewhere in South East Asia, most probably in Malaysia or Indonesia. To trace its precise original home further and to localise it, appears to be merely speculative. Having originated at some place in South East Asia, coconut moved eastwards to the Pacific region and further to America. Towards the west, it moved to India and Madagascar over the calm tropical waters. Apart from sea water, man also played a role in the spread of this indispensable palm. The Spaniards introduced it into the West Indies and the southern shores of the Caribbean sea, the Portuguese introduced into Bahia and other parts of Brazil, the Arabs on the African coast and the maritime Tamils together with the mariners of the Bengal coast distributed it into the lands of the Indian ocean.

12.3 General Morphology

The coconut belongs to the family of palms (Palmæ) included under the lower group of flowering plants known as the monocotyledons. It occupies a conspicuous position in the vegetative kingdom owing to certain characteristic features of the palms, viz., comparatively slow growth, and unusual thickening at the base of the trunk giving mechanical rigidity, generally unbranched, erect, cylindrical, pillar-like stem, covered with heavy scars of old leaf bases, a compact magnificent crown of gigantic, feathery, glossy, thick--cuticled leaves sheathed at base providing firm attachment to the stem, orientated at the top of the trunk rendering a natural beauty and elegance ; a branched inflorescence enclosed in a sheath collectively known as the spadix ; the absence of tap root and the continually growing terminal bud commonly known as the 'cabbage'.

The genus *Cocos* is a monotypic one containing the only species, *Cocos nucifera* Linn (coconut). It is a tall, stately, unarmed palm growing to a height of 12 m to 24 m. The trunk is stout, flexuous, annulate, rarely stands vertically, but makes a gradual curve, raising from a swollen base surrounded by a mass of adventitious roots. The stem is marked by rings of leaf scars which are often not prominent at the base.

The coconut palm has an adventitious root system typical of monocots producing numerous thick roots from the base of the stem almost throughout its life. The roots are localised generally at the lower most region of the stem which has been termed the 'bole'.

Leaves are large, long pinnatisect, borne on the crown ; leaflets equidistant, 60 to 90 cm long, narrow, tapering, linear, lanceolate, coriaceous, flaccid ; petioles stout, 90 to 150 cm long.

Spadix is 1·2 to 1·8 m long, stout, erect, straw or orange coloured, androgynous, simply branched ; branches (spikes) bear one or more female flowers often between two male flowers towards their bases, and several males above ; spathes 2, outer short, inner 60 to 90 cm long, oblong, hard, splitting lengthwise. The palm is monoecious with female flowers relatively few. Male flowers are numerous, small, unsymmetric sweet scented ; sepals small, valvate, petals about 6·4 mm long, oblong, acute, valvate ; stamens 6, filaments sabulate, anthers linear erect ; pistillode minute. Female flowers are larger and fewer than the male, about 2·5 cm long, globose, bracteolate, perianth greatly accrescent, round, concave, imbricate. Petals are shorter than the sepals, convolute with imbricate tips ; disc annular. Ovary is tricarpic, usually one ovuled, sub-basilar.

Fruit is a large 20 to 30 cm long, trigonously obovoid or subglobose, three sided, one seeded drupe. The outer layers of the pericarp are thick and fibrous. The inner layer (endocarp or shell) is very hard, horny or stony with three basal pores or marks representing the remains of 3 carpels or the loci of the ovary, two of which have become obliterated. Under one of these lies the embryo. The thin testa cohering to the endocarp is lined with white albuminous endosperm (meat) enclosing a large cavity, partially filled with sweet fluid.

12.4 Species and Varieties

Species

The genus *Cocos* is a monotypic one containing the only species *Cocos nucifera* Linn.

Varieties

There are two distinct varieties of coconut, the tall and the dwarf. But the natural crossing occurring in coconut is responsible for giving rise to a large scale

multiplication of genetically heterozygous varieties widely varying from each other or groups of closely related varieties. The palm characteristics of tall and dwarf are furnished in Table 1. The varieties differ in size, shape, colour and quality of nuts, shape of crown, leaves, flowers and also trunk characters. Named tall and dwarf varieties of coconut which are well known are furnished in Tables 2 and 3.

Laccadive and Maldivi Dwarf, Andaman Dwarf, Chennangi and Gangabondam in dwarf are a few common varieties in India. In tall, Fiji, S. S. Green, San Ramon, Phillippines Ordinary are found superior to the West Coast Tall variety. The performance of the varieties Laccadive Ordinary, Laccadive Micro, Andaman Ordinary and Kappadam and of certain hybrids, Tall × Dwarf, Tall × Gangabondam, Laccadive × Gangabondam, Dwarf Orange × Tall have also been reported encouraging. The morphological and yield characteristics of T × D and parental types are furnished in Table 4.

TABLE 1. SOME CHARACTERISTICS OF THE DWARF TYPES AND THE ORDINARY TALL

	Dwarf Green	Dwarf Orange	Ordinary Tall
Age at first flowering (years)	3	4	7
Girth of stem (cm)	50·8	53·3	66·0
No. of leaves on the crown	26·0	28·0	32·0
Length of leaf (m)	2·93	3·14	3·84
Width of leaf (m)	1·46	1·83	2·65
Length of petiole (m)	0·91	1·19	1·31
Annual yield of nuts	66·0	90·8	66·0
Copra content per nut (gm)	92·14	99·23	170·10
Calculated annual yield of copra per tree (kg)	6·081	9·010	11·227
Quality of copra	poor	poor	good
Percentage of oil in copra	73·54	66·13	74·30
Free fatty acid content (%)	0·02	0·07	0·20
Size of nut-girth (cm)	34·3	38·1	55·9
Thickness of kernel (cm)	0·8	0·8	1·3
Volume of water inside (gm)	255	510	680
Mean number of days taken for germination	49·3	60·7	95·0
Flowering—male phase	8th–20th day	6th–18th day	1st–19th day
Flowering—female phase	15th–16th day	17th–19th day	21st–23rd day
Pollination	Self	Self & cross	Rarely self

TABLE 2. NAMED TALL VARIETIES OF COCONUT PALM

Long, angular fruit, thick husk, long, pointed nut, thick shell, little water	Fruit and nut characteristics intermediate between the types		Spherical fruit, thick husk, spherical nut, thin shell, much water
Small fruit	*Medium fruit*	*Large fruit*	*Very large fruit*
Atuabo	Ceylon tall	Manila	Kamandala
West African Tall	Indian Tall	Coco Redondo	Andaman Giant
Mnazi	Laccadive Ordinary	Philippino	Kappadam
Mozambique	Gangabhavani	Panama Tall	Rangoon Kobhari
Seychelles Tall	Harmania	Andaman Tall	Ka Loke
Tres Picos	Narikal	Maprao-Yai	San Ramon
San Blas	Park-choke	Thailand Tall	Markham Tall
Jamaica Tall	New Hebrides Tall	Malayan Tall	Niu Vai
		Java Tall	Rennel Tall
		Klapa Dalam	Thifow
		Laguna	
		Lupisan	
		Davao Tall	
		Bougaineville Tall	
		Kar Kar Tall	
		Rotuma Tall	
		Niu Kitu	
		Tonga Tall	
		Tahiti Tall	

TABLE 3. NAMED DWARF VARIETIES OF COCONUT PALM

Ovoid fruit, thick husk : ovoid nut, thick shell	Ovoid fruit, thin husk ; oblate nut, thin shell, much water
Cameroon Dwarf	Gon Thembili
Regia	Fumila
Chowghat Green	Eburnea
Maldivi Dwarf	Chowghat Orange
Kelapa Radja	Gangabondam
Coco Nino	Laccadive Dwarf
Pilipog	Malayan Dwarf
Nok-koom	Kelapa Gading
Haari Papua	Mu-See-Keo

TABLE 4. MORPHOLOGICAL AND YIELD CHARACTERISTICS OF T×D AND PARENTAL TYPES AT NILESHWAR

Characteristics	T×D	Tall	Dwarf (Green)
Height of palms (cm)	618·0	621·6	360·0
Girth (cm)	65·9	64·6	55·0
Total number of leaves produced	395·7	349·3	415·0
Number of functional leaves	28·5	29·6	22·0
Annual rate of leaf production	13·5	12·0	13·6
Average annual yield of nuts	75·3	54·0	113·0
Average nut weight (kg)	1·16	1·188	0·400
Average weight of husked nut (kg)	0·900	0·600	0·100
Average weight of shell (kg)	0·091	0·135	0·027
Average weight of kernel (kg)	0·237	0·220	0·052
Average copra outturn per nut (kg)	0·187	0·171	0·038
Oil percentage	70·1	71·7	65·6

12.5 Soil and Climate

Soil

Coconut is adaptable to a wide range of soil conditions. The crop is grown under extreme conditions of soil which vary from sand to the heaviest clays. It does well in light, easily permeable soils with slowly moving sub-soil water at a shallow depth. It can, however, be grown on heavier soils provided they are well drained. It equally performs well on white or gravelly sand, alluvial soils, laterite or lateritic soils, peaty soils, vulcanic and pumice soils and marine and coastai soils. Yield is high if the soil and gravel depth is more, the critical depth being 120 and 60 cm. respectively. Coconut roots are very thick and cannot penetrate in compact soils. Fluctuating water table restricts root development. Poor drainage and high water table also cause physiological drought. Kerala soils are lateritic and acidic in nature. In alluvial and red loamy soils the palm comes to bearing early, while this period gets prolonged, considerably in lateritic and sandy soils with low water table. The palm can be grown in soils with a pH ranging from 5·2 to 8·0.

Climate

The coconut palm is not very exacting in its climatic requirements and is highly adaptive to a variety of environments. But the likes and dislikes of this palm should be given due consideration for ensuring the development of a profitable and prosperous coconut industry.

The coconut is essentially a tropical plant (John, 1952). Over 90 per cent of the world's total acreage and production of the crop lies between 20°N and 20°S latitudes. The palm is also grown beyond this zone up to 27°N and 27°S to a very small extent. In extreme north and south, the coconut is reported to put on good vegetative growth but does not bear fruits satisfactorily. The palm is extensively cultivated in altitudes ranging from 600 to 900 m in various countries. But reports are available showing establishment of successful gardens even at an elevation of 1350 metres. However, the altitude again is interlinked with latitude, thus the determinant factor in both the cases is providing an ideal temperature. At places further away from equator, one can go in for much low land whereas in places near the equator gardens can be established well at a fairly higher altitude (Menon and Pandalai, 1958).

Of all the climatic parameters, rainfall and temperature appear to be the most important ones. The optimum total rainfall per annum is between 1,300 and 2,300 mm. Rainfall shows the greatest effect on palm girth, setting of female flowers and nut development. If the annual total rainfall falls below 1,000 mm or is distributed very unevenly, the growing of coconut becomes difficult. Heavy rains over a shorter period prevent pollination. Severe drought at the flowering period may kill the growing point causing the inflorescence to abort. This will affect production of nuts up to 28-30 months that follow. Rainfall during the first three months of nut development determines the size of the crop per year later (Davis *et al*, 1982).

Positive relationship between rainfall over a period of six months and the amount of copra per nut per year has been established, while temperature and relative humidity act negatively. The coconut cannot bear prolonged drought and the effect can persist for 2½ years in which case the weight per nut is reduced.

Temperature in fact determines the altitude and latitude in which coconut can be grown. The optimal mean annual temperature for the best growth and maximum yield is considered to be about 27°C with a diurnal range of 6-7°C. In coastal areas, there is less fluctuation in temperature. The major producing areas are located in regions having a temperature range of 20 to 32°C. High temperature interferes with pollination (Henry Louis and Annappan, 1980). A warm and humid condition is preferred by coconut. Persistence of highly humid conditions throughout is, however, not conducive for two reasons. One is that it reduces transpiration and thereby limits nutrient uptake ; secondly, it favours rapid spread of dreadful diseases like bud-rot.

The palm requires plenty of sunlight and does not grow well under shade or in too cloudy regions. The lean and lanky growth and unproductiveness of palm growing in shade is an evidence of this. The copra yield has been related to the hours of sun shine during the final maturation period of nuts. There is considerable reduction in yield if the sunlight available is less than 2,000 hours per annum or 120 hours per month. Supplementary illumination given throughout

the year to West Coast Tall palms tend to increase the palm vigour besides promoting inflorescence primordia. But subsequent abortion of initiated primordia stands in the way. If only this could be avoided, there is scope of reducing the pre-bearing age of the palm considerably (Pillai *et al*, 1972).

12.6 Area and Production

The major coconut growing countries of the world are found in Asia, Oceania, West Indies, Central and South America, East and West Africa. The crop is estimated to be grown in an area of about 9 million hectares with an annual production of 33,700 million nuts. The area and production of coconut in major growing countries are presented in Table 5.

The Philippines leads in the world area under coconut, accounting for 36·6 per cent followed by Indonesia with 26·9 per cent. India figures third in world acreage accounting for 12 per cent of the production. Table 6 gives the distribution of area and production of coconuts in India. The annual production in India is estimated to be around 5,733·6 million nuts from an area of 10,82,900 hectares. A considerable amount of foreign exchange is realised tnrough coconut and in 1977 coconut was exported to the tune of 1,776 million rupees. Kerala is the major producer in the country with about 7 lakh hectares which accounts for 65 per cent of the area.

TABLE 5. AREA AND PRODUCTION OF COCONUT IN SELECTED COUNTRIES OF THE WORLD

Country	Year of reference	Area (000 ha)	Percentage (Area)	Production (million nuts)	Percentage (Production)
Philippines	1978	3,317	36·6	12,882	38·1
Indonesia	1978	2,435	26·9	7,265	21·5
India	1978	1,083	12·0	5,734	17·0
Sri Lanka	1978	466	5·1	2,258	6·8
Thailand	1978	400	4·4	550	1·6
Malaysia	1978	325	3·6	844	2·7
Papua New Guinea	1978	252	2·8	798	2·4
Fiji	1978	60	0·7	155	0·5
Western Samoa	1978	40	0·4	218	0·6
Zanzibar	1971	49	0·5	154	0·5
Solomon Islands	1978	34	0·4	185	0·6
Other areas	---	600	6·6	2,600	7·7
Total		9,061	100·0	33,693	100·0

TABLE 6. AREA AND PRODUCTION OF COCONUT IN INDIA

States	Area (000 ha)	Percentage (Area)	Production (million nuts)	Percentage (Production)
Kerala	699·1	64·6	3,366·5	58·7
Tamil Nadu	109·4	10·1	1,035·5	18·1
Karnataka	155·6	14·4	815·5	14·2
Andhra Pradesh	39·8	3·7	164·6	2·9
Maharashtra	9·3	0·9	49·9	0·9
Orissa	13·8	1·2	58·9	1·0
West Bengal	6·7	0·6	22·0	0·4
Assam	4·9	0·4	31·0	0·5
Goa, Daman, Diu	18·7	1·7	86·0	1·5
Andaman and Nicobar	20·4	1·9	65·7	1·1
Lakshadweep	2·8	0·3	21·8	0·4
Pondicherry	1·6	0·1	15·1	0·3
Tripura	0·8	0·1	1·1	---
Total	1,082·9	100·0	5,733·6	100·0

12.7 Propagation

Seed propagation

In a perennial crop line coconut which exhibits considerable genetic variations and is being propagated only through seeds, the selection and use of planting material of higher intrinsic value assume much importance (Thampan, 1982).

Selection of seed centres

In every country where coconut has been under cultivation for a long period, certain centres are found to have earned a reputation for the yield and quality of nuts. In the important coconut growing regions of India, a number of such centres of repute are known and the results of a critical and comparative evaluation of these centres in regard to the germination of seed nuts and the outturn of quality seedlings are available. Only such centres are to be identified for seed gardens (Aiyadurai, 1954).

Selection of seed nut

Nuts should be collected from gardens with a record of consistently high yields which comprise a high proportion of heavy bearers, and situated under average conditions without heavy manuring or irrigation and free from the incidence of pests and diseases.

Selection of mother palm

In the selection of mother palms the following characters are looked for :

(i) The crown should be spherical or semi-spherical. Drooping or erect crown should be avoided.
(ii) The length of petiole and bunch stalk should be short and stout.
(iii) The nuts should be medium in size and nearly round or spherical.
(iv) The bunches should have a preponderance of heavy nuts.
(v) The trees producing barren nuts should be discarded.
(vi) The palms should be between the age group of 25–60 years.
(vii) The palms growing close to houses, cattle sheds, compost heaps, etc., may be avoided as it is difficult to identify inherently good trees.

Collection of seed nuts

The time of harvest of seed nuts may vary in different regions. The considerations that weigh in this connection are the general development of nuts, their capacity for germination, the period of storage required and the facilities for planting in the nursery (Aiyadurai, 1954). On the west coast of India, seed nuts are harvested during February to May. The nuts should be 11 or 12 months old (Liyanage, 1950). The seed nuts should be cut and lowered by ropes to avoid any damage. The seed nuts are arranged by their stalk-end up on the floor of a shed over a layer of about 7·5 cm dry sand and completely covered with it till the planting time.

Nursery-site selection and preparation

The best soil for a nursery is sandy soil near a water source which will provide effective drainage and prevent termite attack. The area should be open and free of shade. If sandy areas are not available, it is better to remove 0·3 to 0·5 metre depth of soil and fill with sand. The seed beds should be preferably long and narrow with provision for walking space or drains in between. The width is so adjusted as to take in 4 or 5 rows of nuts only.

Planting of seed nuts

Different methods of planting are in vogue. Some plant horizontally, while others vertically with stalk-end up or in an oblique position. Even planting upside down has also been in practice. Though horizontal planting has been critically found to be the best (Ambrose, 1951 ; Espino, 1922), vertical planting has been widely practised in India as the seedlings are easily transported without damage. The widest of the three segments should be placed uppermost in horizontal planting. Usually the seedlings, that develop from nuts planted upright, suffer more from drought and are less robust than those that develop from nuts planted flat (Pieris, 1937). Another advantage of horizontal planting is that seedlings from horizontally placed nuts are less likely to be damaged at transplanting because

the attachment between shoot and nut is much better protected by the husk (Sampson, 1923). Seed nuts buried completely performed better than those half buried (Ballesteros, 1965). In an experiment carried out in Papua New Guinea, it was found that the rate of germination and subsequent growth of seedlings were much faster in horizontal planting than in vertical planting. In eight weeks from planting, 47 per cent germination was recorded for horizontal planting as compared to 39 per cent for vertical planting (Kenman, 1973). Among the many pre-sowing treatments recommended for reducing the period of germination, soaking the seed nuts in water for two weeks prior to sowing has been found to be very effective. In a trial in Tanzania, this treatment recorded the lowest period for germination (81·1 days) in comparison with 142·9 days for untreated seed nuts (Thomas, 1973). The spacing between nuts varies from 25·4 to 38 cm. In Sri Lanka 22 cm spacing on either side is adopted. The depth should be so adjusted that the husk appears just above the surface which is generally 15 cm. The planting of nuts are generally done in monsoon as the cost of nursery watering can be considerably reduced.

Management of nursery

The seed beds should be watered twice a week and kept free of weeds. During dry and hot periods, coconut leaf mulch has been reported to promote early and better germination, good growth of seedlings and to give high percentage of good seedlings (Liyanage, 1952 ; Verghese *et al*, 1953).

Manuring and fertilisation at the nursery stage

Recent studies on the nutrient requirement of seedlings indicate that fertilisation is necessary if seedling vigour is to be maintained in the nursery. It has been observed that the seedling begins to take up the nutrients immediately after the emergence of the first roots which is about fourteen weeks from sowing. In Sri Lanka, it was observed that up to 30 weeks in the nursery the seedling was self-supporting in nitrogen. The growing part of the seedlings indicated the need for additional potash (Child, 1964). In the Philippines, results of experiments on mineral nutrition of coconut seedlings showed very good response to the dressings of sodium chloride and potassium chloride. While phosphorus had no effect on the growth of seedlings, sodium chloride and potassium chloride had a positive influence on the height and girth of seedlings at the stage of six months. The experience in India had shown that nursery manuring is not necessary if the seedlings are to be removed about nine months after setting the seed nuts and after that the seedlings may respond to fertilisation if the soil is not fertile. A careful watch should be made on pests and diseases, especially termites.

Selection of seedlings

The nuts of tall variety commence germination in 11 to 12 weeks after planting under favourable conditions. The nuts which fail to germinate within 6 months

are discarded. Proper selection of seedlings in nursery alone ensures 10 per cent improvement in yield (Liyanage, 1953). Early germination, rapidity of growth, early splitting of leaves into leaflets, vigour, sturdiness and freedom from diseases and pests are the characters looked for. The seedlings are removed from nursery only just before they are required for transplanting in the field. The roots should be dug out neatly and the nuts gently removed. The seedlings should be at least 9-12 months old at planting. In general, seedlings of 9-18 months can be considered the best for planting.

Vegetative Propagation

Unlike many other fruit plants, only partial success has been achieved in the vegetative propagation of coconut palm. Propagation by air-layering of the crown has been reported by Davis (1969). It may help in the rejuvenation of old palms or those growing in unfavourable locations. Another method is to divide the growing shoot apex of young seedling and induce to form branches or suckers. The suckers may be separated after rooting. This method does not ensure that the separated plant will develop into a superior palm.

The other methods of vegetative propagation which are being attempted include tissue culture technique and conversion of floral branches or individual flowers into vegetative shoots, commonly known as bulbils.

12.8 Cultivation

Preparation of land

In slopy areas, terracing and anti-erosion measures should be done (Frederick, 1953 ; Gorrie, 1950). In low lying areas, where water is likely to stagnate, drains should be made to remove excess water.

Preparation of pit and planting

Pits of 1 m cube or 1·5 m cube depending upon the soil are dug up and planting done at depths varying from 60 to 75 cm below the ground level. The pits are usually dug two to three months in advance and allowed to weather. Just before planting a mixture of sand and surface soil to a depth of 30 cm is applied. Different depths of planting are adopted in different countries. It may range from 15 cm under water logged conditions, 30 cm in a well drained soil and 45 cm in dry areas. It is a good practice to spread two layers of coconut husk at the bottom of the pits in areas where drought conditions prevail. Coconuts planted at 60 cm to 90 cm depths can withstand cyclone. At 60 cm depth significantly more number of leaves in the crown (8·5%) were recorded than in surface

planting (Vijayan *et al.* 1979). The seedling is placed at the centre of the pit in such a way that the top of the husk is just visible from outside. The earth is well-pressed down in order to keep the seedling firmly in position.

Planting distance

The choice of a spacing standard for the coconut depends upon whether the crop is grown in monoculture or in association with other crops, whether perennial or seasonal in character. In monoculture, spacing is adjusted in such a way as the fronds of the adjacent palms do not overlap when fully grown and there should be no competition for nutrients, moisture and sunlight. Different spacings advocated were (i) triangular planting at a distance of 10 m giving 115 palms per ha, (ii) triangular planting at a distance of 9·2 m giving 140 palms per ha and (iii) a population of 184 palms per ha at a distance of 8 m (Sampson, 1923). In India, a spacing of 7·5 to 9·0 m for a pure crop of ordinary tall variety is recommended. In Sri Lanka, a square planting distance of 8 to 8·5 m is normal. The general consensus in Sri Lanka is that the population should not exceed 160 palms per ha on the worst soils and 138 palms on the best (Child, 1964). In West Malaysia, 8·8 or 9·1 m in the square method is normally followed A spacing of 6·5 to 7 m on the square is recommended for dwarf palms. For mixed plantations, spacings range from 8·5 to 10·7 m for tall varieties. In West Africa, a density of 143 palms per ha has been found to give a better economic return (Charles, 1968). There are four systems of planting, viz., square, triangular, rectangular and quincunx of which the first two are more commonly adopted (Ganarajah, 1954). The triangular system accommodates about 15 per cent more palms in a unit area. Table 7 gives the number of palms per hectare in square and triangular systems.

TABLE 7. NO. OF PALMS/HECTARE IN RELATION TO PLANTING DISTANCE AND SYSTEM OF PLANTING

Planting distance (m)	No. of palms per ha	
	Square system	Triangular
6·7	225	260
7·0	205	235
7·3	190	217
7·6	175	200
8·0	160	184
8·3	150	167
8·6	140	160
8·9	130	150
9·2	120	140

Closer spacing ensures more yield in an unit area though yield per tree decreases (Whitehead and Smith, 1968). The yield and profit per hectare in different spacings are presented in Table 8.

TABLE 8. PLANTING DISTANCE AND YIELD

Planting distance (m)	Palms/ha	Yield (nut No./ha)	Profit (Rs.)
12·2 × 6·5 10·6 × 7·3	128	10,589	5,843·56
12·2 × 5·5 10·6 × 6·5 9·2 × 7·3	150	11,234	6,145·00
12·2 × 4·5 10·6 × 5·5 9·2 × 6·5 7·6 × 7·3	175	11,979	6,490·50
10·6 × 4·5 9·2 × 5·5 7·6 × 6·1	200	12,447	6,672·00
9·2 × 4·5 7·6 × 5·5	239	12,948	6,818·50

Of late, double row system of planting to accommodate 600 palms per hectare has been found to give a net profit of Rs 10,600/ha. But it is seen that when the palms are closely planted they take much more time to commence bearing than when they are planted at an optimum distance. Another useful development in coconut spacing is the hedge planting methods (Liyanage, 1955). It is a common observation that despite the stringent selection methods right from mother palm selection to the seedling, a coconut garden will have 30 per cent of poor yielders which bring down the mean yield considerably. Hence, in hedge system seedlings more than necessary are transplanted in a unit area by adopting a wider inter-row spacing and closer intra-row spacing. Undesirable plants as judged by the initial growth are removed at different stages so that the ultimate stand is composed of only high yielding palms.

Irrigation

The palms are massive and thick, perennial in nature and require large quantity of water for normal growth and functioning. A single functioning root of coconut can absorb 400 ml of water in a day. An adult palm normally produces 4,000-7,000 such roots. This means a minimum of three litres of water can be absorbed per day, and it may go up to as much as 24 litres. The transpiration loss per day is 28-74 kg of moisture. Irrigation improves bunch production

and copra yield, increases the total number of female flowers, and decreases immature and mature nut drops, while water deficiency not only affects setting of nuts but also results in severe shedding of buttons and immature nuts. The palms irrigated once in 10 days gave 53·5 per cent more yield, while those irrigated at 15 days interval gave only 15·4 per cent increase than the unirrigated ones.

In west coast, rains are received only for 7 months and the remaining five months are considered drought. Moisture content during summer goes down to 0·1 per cent. Irrigation during summer once or twice a week can increase yield by 25-30 per cent. Application of bulky organic matter to increase the organic matter content in soil by one per cent aids to retain 2500 gallons of more water in the soil. Burying coconut husk in between rows in pits of 1·5 m width and 6 cm depth once in five years helps in saving water in addition to enrichment of potassium (1-3%). Application of clay or river soils, intercultivation and mulching practice also help in improving the soil moisture status. Absence of adequate moisture in soil affects the absorption of nutrients also. Potassium absorption has never been optimum under inadequate moisture availability in the soil (Chacko, 1979).

Manuring and fertilisation

Application of fertilisers in general reduced the prebearing age of palms (Cooke, 1954). Number of palms flower decreases with increasing levels of nitrogen but increases with increasing levels of phosphorous. Nitrogen increases trunk height, leaf production, bunch number (11·7-12%), female flowers and nuts (16·9%) but adversely affects copra content and setting percentage. Potassium improves leaf area, leaf colour, setting of female flowers and size and weight of nuts. The effect of phosphorous alone is negligible but is beneficial in the presence of nitrogen and potassium (Nelliat, 1973). Deficiency of calcium causes reduction in root girth, while boron deficiency causes rotting of crown, bud and leaf. The effect of potassium is more pronounced when required quantities of iron, manganese and nitrogen are available. Iron deficiency symptoms are expressed when the iron content of the 14th leaf falls below 50 ppm.

The production of leaves and the number of functioning leaves are highly influenced by magnesium. Both the characters may be jointly responsible for earliness in flowering (Kamalakshiamma and Pillai, 1980). Root wilt incidence has not been influenced by calcium and magnesium. However, application of magnesium increases the yield of coconut in root wilt affected areas. Magnesium application can be done as oxide of magnesium at the rate of 500 gm per palm or as ground dolomite or epsum salt. Other elements like chlorine, sodium and sulphur have beneficial effects on the setting of fruits, hardening of kernel and on the copra qualities. In coconut, zinc deficiency can cause dwarfed and deformed growth of tender leaves called 'rosette' or 'little leaf' formation. Boron deficiency also causes malformation of young leaves and production of barren nuts. The micro

nutrients in general improve the productive capacity of the palm, particularly in acid laterite soils with high phosphate fixation capacity.

Application of organic matter tends to improve the retentivity of potassium in soil and also enhances iron and manganese absorption as indicated by their higher levels in the leaf. The seedling mortality is less in plots applied with organic matter (Nambiar *et al*, 1978). As regards the different forms of nitrogen, there is no significant difference between the organic and inorganic forms and also between urea and ammonium sulphate whereas the latter tends to make the soil acidic and is somewhat higher in cost. Different estimates of the average annual removal of the macro nutrients have been reported by several research workers (Table 9).

TABLE 9. ESTIMATES OF ANNUAL REMOVAL OF PLANT NUTRIENTS FROM THE SOIL BY THE COCONUT PALM

Nutrients kg/ha					
N	P_2O_5	K_2O	CaO	MgO	
20·2	5·6	42·6	—	—	Pillai (1919)
63·9	29·1	95·3	—	—	Jacob and Coyle (1927) Copeland (1931).
91·9	41·5	136·7	23·3	38·4	Recalculated by Nathanael (1967)
74·0	30·3	137·9	17·6	32·1	Georji and Teik, (1932)
90·8	40·4	131·1			Eckstein *et al*, (1937)
26·9	13·5	67·3			Patel (1938)
116·6	40·4	141·2			Carvalho (1947)
58·3	17·9	53·8	29·1	44·8	Cooke (1950)
67·8	27·3	100·7	23·3	38·4	Overall average.

In Sri Lanka, the estimates made on the gross annual removal of nutrients by an average palm producing 43·75 nuts per annum were in the order of 0·6 kg N, 0·26 kg p_2O_5, 0·87 kg K_2O, 0·15 kg CaO and 0·25 kg MgO. In the case of a palm with an estimated annual production of 93·75 nuts the corresponding figures were 0·75 kg N, 0·33 kg P_2O_5, 1·1 kg K_2O, 0·17 kg CaO and 0·28 kg MgO.

A series of experiments on fertilisation, conducted at the Central Plantation Crops Research Institute, Kasaragod, Kerala, have provided very useful results of practical significance. In one such experiment it was found possible to raise the yield of palms grown under neglect for long from a mere 17 nuts to 57 nuts per palm per year in the course of five years by the application of a balanced mixture of fertilisers as shown in Table 10 (Nambiar *et al*, 1978).

A spacing cum fertiliser experiment conducted at the Regional Research Station, Veppankulam, Tamil Nadu, revealed significant response of palms to NPK

TABLE 10. YIELD OF NUTS FROM NEGLECTED PALMS UNDER DIFFERENT TREATMENTS

Treatments	Year I	II	III	IV	V	Mean yield of nuts per palm per year
T_1	NIL	NIL	NIL	NIL	NIL	17
T_2	0·33F	0·66F	F	F	F	30
T_3	0·5F	F	F	F	F	45
T_4	F	F	F	F	F	49
T_5	2F	F	F	F	F	57
T_6	2F	2F	F	F	F	57

F indicates full dose of 500 gm N, 320 gm P_2O_5 and 1200 gm K_2O per palm per year.

fertilisation. The cumulative yield data for the period 1966-1974 showed an increase of 365 per cent over the control due to the application of 340 gm N, 227 gm P_2O_5 and 454 gm K_2O per palm per year. Doubling the above dose resulted in an increase of 534 per cent over the control.

The fertiliser trial carried out in Jamaica showed large and significant increase in growth and yield as a result of fertiliser application. The conclusions drawn were,

(i) coconuts, in general, respond to fertilisers and are likely to give an economic increase.

(ii) the real extent of the response becomes manifested only after several years of regular fertilisation.

(iii) a high potash in the fertiliser mixture is desirable but application of potash alone will not yield maximum dividend.

A summary of the results of 11 fertiliser experiments carried out in Jamaica in 1961 had brought out convincing data which are presented in Table 11.

TABLE 11. MEAN NUMBER OF NUTS SET PER PALM

Treatments	Mean number of coconuts 6, 12 and 18 months after commencing	Mean number of coconuts 29, and 30 months after commencing
Fertiliser	60·81	66·75
Control	50·16	50·58
Percentage of increase	20·80	32·00

In Ivory Coast, based on many fertiliser experiments, the optimum economic rates for the most important nutrients have been fixed at 2 kg of potassium chloride, 0·7 kg of bicalcic phosphate and 0·9 kg of keiserite per palm per year (Coomans and Ochs, 1967).

In Puerto Rico, in a four-year experiment involving the application of 900 gm each of ammonium sulphate, superphosphate and potassium sulphate singly and in

all possible combinations twice annually, the beneficial effects of potash were evident. The influence of potash was greater than that of nitrogen. Phosphoric acid was only slightly beneficial when applied alone or in combination with potash but reduced the effect of nitrogen. The increase in yield for NK application was 43·7 per cent, for NPK 26·9 per cent and for NP only 3·2 per cent (Almeyda, 1959).

In Fiji, fertiliser trials conducted during 1970-71 resulted in favourable yield response to NPK. The response to ammonium sulphate ranged from 140 to 310 kg copra per ha per year and to superphosphate it was 250 kg copra per ha per year (Vernon *et al*, 1976).

A review of the results of field experiments conducted in Sri Lanka has shown that while the poor laterite soils could give as much as 200 per cent increase in yield, the richer soils could give only 30 per cent for the annual application of 1·5 to 2·25 kg of fertilisers per palm (De Silva, 1967 and 1973). In another experiment, it was found that from fertiliser application the return per unit investment was found to be 107 per cent more after the first year which increased progressively to 447 per cent in about the 10th year (Abeywardena, 1975). The fertiliser trials conducted in the Philippines had shown that application of 1·5 kg ammonium sulphate and 1·60 kg potassium chloride per palm increased the yield from the second year of application. Copra yield went up to 149 per cent (29·50 kg per palm) in the seventh year with an average of 135 nuts per palm as compared to 84 nuts (11·87 kg copra per palm) in the control plant. (Mendoza and Prudents, 1972).

Foliar diagnosis as an index of fertiliser requirement

It is possible to measure the degree of nutrient deficiency by foliar analysis, and to determine the level at which the fertiliser should be added. In adult palms, more than five years old, frond 14 is taken up for analysis, while in young palms frond 4 is used for the purpose. For the purpose of sampling, the youngest open leaf is taken as number one and by counting successively the older leaves, the 14th leaf is identified. The leaflets obtained from either side of the middle portion of the 14th leaf are sampled and the middle portion of the leaflets, after discarding the ribs is analysed. Samples are usually taken from about 20 per cent of the palms in a garden and bulked together.

In the Philippines, the foliar nutrient levels were reported as follows : N 1·95%, P 0·22%, K 1·44%, Ca 0·28% and Mg 0·22% in the case of palms which yielded 102 nuts per palm per year (Von Uex Kull, 1971). In Jamaica, a level of 1·8 to 1·9 per cent nitrogen has been recommended in frond 14. In the case of potash, a minimum level of 0·8 per cent has been stressed and a fertiliser schedule to that effect has been recommended (Romney *et al*, 1968). In Sri Lanka, the analysis of the 14th leaf showed the level of major nutrients as N 1·98%, P 0·133% and K 0·87%. In Malaysia, the foliar nutrient levels in the dwarf, semitall and tall varieties of the coconut were established and are given in Table 12.

TABLE 12. OPTIMUM FOLIAR NUTRIENT LEVELS FOR DIFFERENT VARIETIES IN THE 14TH LEAF (expressed as per cent dry matter and ppm for micro nutrients)

	N	P	K	Ca	Mg	Mn	Fe
Tall	1·8	0·12	0·8-1·1	0·15 0·30	0·30	60	45
Semitall	1·8-2·0	0·12	0·8-0·90	0·15-0·30	0·30	60	45
Dwarf	1·9-2·0	0·12	0·75-1·0	0·15-0·30	0·30	60	40

Fertiliser recommendations

In India, based on the experimental findings at the Central Plantation Crops Research Institute, Kasaragod, a fertileser schedule is given in Table 13. The recommended nutrients can also be made available by the application of a complete fertiliser mixture of N, P and K in the ratio of 10 : 5 : 20 at the rate of 3·5 kg for the rainfed tall variety and about 6 kg for hybrids and irrigated talls per palm per year. The inorganic fertilisers are recommended to be applied over and above an annual basal dressing of green leaves or compost at the rate of 25 to 50 kg per palm along with 2 or 3 kg ground dolomite/limestone or 50 gm magnesium sulphate per palm. In Sri Lanka, the fertiliser mixtures are based on the different soil groups. The recommended quantity of fertilisers per palm per year is 3·5 to 4·5 kg of any one of the mixtures of N, P and K in the ratio of 10·3 : 5·5 : 18·0 ; 10·3 : 6·1 : 16·6 ; 10·3 : 5·5 : 18·0 and 10·3 : 6·85 : 15·0.

TABLE 13. GENERAL FERTILISER RECOMMENDATION FOR BEARING ADULT PALMS IN INDIA

Nutrient	Dosage (kg)		Name of fertiliser	Qty. to be applied per palm per year (kg)	
	Ordinary tall rainfed	Hybrid and tall irrigated		Ordinary tall rainfed	Hybrids and tall irrigated
Nitrogen	0·34	0·5	Ammonium sulphate or	1·7	2·5
			Calcium ammonium nitrate or	1·7	2·5
			Urea	0·7	1·0
Phosphoric acid	0·17	0·34	Superphosphate or	1·0	2·0
			Ultraphos	0·5	1·0
Potash	0·68	1·20	Muriate of potash	1·2	2·0

In Jamaica, for soils low in nitrogen and high in potash content, an annual dose of 1·8 kg of sulphate of ammonia alternated with 900 gm of 12 : 8 : 30 fertiliser mixture is recommended. For soils low in potash, the recommendation is to apply 1·4 kg of 12 : 8 : 30 fertiliser mixture and 1·4 kg of muriate of potash per palm per year. In Ivory Coast, separate fertiliser schedules have been suggested for tall variety coconuts and hybrids (Magat, 1978).

Methods of application of fertilisers

Various local practices are in vogue for the application of fertilisers to the palm. In India, different methods adopted are broadcasting, basal application and application in mammatty holes. A trial conducted at Kasaragod in 1957, recorded a yield increase of 11·5 per cent by broadcasting, 11·1 per cent by basal application and 10·9 per cent by application in mammatty holes. In Jamaica, broadcasting of fertilisers on the soil surface in a trench round the tree is practised. In Malaysia, it was recommended that the fertilisers should be applied in a shallow trench round the base of the palm at a radius of 2 m from the base.

A study in India on the rooting pattern of the palm, showed that in a regularly cultivated and manured plot 74 per cent of the emerging roots did not extend beyond 2 m and only a few roots were met within the first 30 cm layer of soil. About 82 per cent of the roots were confined to 31 to 120 cm depth of soil (Kushwah *et al*, 1972). In Sri Lanka, studies using radioisotope of P_2O_5 (P^{32}) showed that fertiliser application in the entire area round the palm up to a distance of 2 m from the bole recorded an uptake efficiency of as much as 100 per cent more than that of broadcasting, circular trench, or circular strip methods. Application in full circles was about 40 per cent more efficient than half circle application (De Silva, 1968). In the Philippines, the recommendation is to broadcast fertilisers up to a distance of 2 m from the bole followed by digging the surface soil to a depth of 10 to 15 cm.

Frequency and time of application

For deriving maximum benefit in all types of soil and form of fertilisers, it is necessary to apply fertilisers in small quantities at frequent intervals (Markose and Nelliat, 1975). The time of application of fertiliser is influenced by the soil moisture conditions. The appropriate time is when the soil is neither too dry nor too wet. Periods of heavy rain and long spells of dry seasons should be avoided.

Inter and multiple cropping

In a pure coconut garden when palms are spaced at 7·5 m × 7·5 m, as much as 78 per cent of the available area is not effectively utilised. It is also seen that a pure coconut grove utilises only half of the available light. Introduction of cacao, pineapple and pepper has been found to help increase the dry matter production from 12·67 per cent to 19·3 per cent under Kerala conditions. In a crop combination involving coconut, dioscorea, cacao and pineapple, 17,500 coconuts, 100 kg of dioscorea tubers, 300 kg of dried cacao beans and 2,000 kg of pineapple fruits were harvested from one hectare. The increased income through multiple cropping is about 420 per cent more than that obtained from a pure crop of coconut. The beneficial effect of crops has also been brought to light wherein introduction of cacao improved the yield of coconut up to 76 per cent (Thomas, 1978). The yield of coconut has been reported to increase by 68 per cent

and 116 per cent in single and double row systems, respectively (Verghese *et al*, 1953). In addition to the increased yield, additional labour requirement have also been created from 226 man days a year per hectare as against 150 man days only in a pure coconut grove. If tapioca also is introduced, the man days required is increased to 400. Such systems also provide for more economic stability through minimising crop losses, saving the cultivation expenses and providing income round the year. The economics of intercropping with a few crops have been worked out and presented in Table 14.

TABLE 14. ECONOMICS OF INTERCULTIVATION OF CERTAIN CROPS

Inter crops	Percentage of groves area utilised	Net return (Rs/ha)	Net return per rupee invested
Elephant yam	80	3,600	1·28
Tapioca	80	2,400	1·37
Sweet potato	70	1,700	1·00
Ginger	65	10,260	2·46
Turmeric	65	1,200	0·29
Golens	65	3,100	1·83
Yam	80	4,000	1·70

In general, crops like pepper, betelvine, pineapple, banana, cacao, clove, nutmeg, cinnamon, elephant yam, tapioca, dioscorea, ginger and napier grass have been found feasible for growing in coconut gardens.

12.9 Flowering, Floral Biology and Pollination

Flowering

In a bearing coconut palm every leaf axil can produce a spadix or inflorescence which under normal conditions varies from 12–15 annually. However, this number may be reduced due to adverse weather condition. The inflorescence develops within a strong, tough, pointed double sheath called spathe which after full development splits along its underside from top to bottom and releases the inflorescences. This usually occurs from 75 to 90 days after the first appearance of its tip in the leaf axil. The primordia of the inflorescence begin to form in the leaf axil about 32 months before the opening of the spathe.

The coconut palm is monoecious and produces several hundred male and a few female flowers on the same inflorescence. It bears about 30–35 spikelets, each having about 250–300 male flowers at its top and one or a few female flowers at the base. The number of female flowers produced by an inflorescence is influenced by the season, soil conditions, variety and the inherent yield potential of the plam. In India, the female flower production is high during the period from March to

May and low from September to January. In general, the number of female flowers per inflorescence varies from 10–50 although figures outside this range are also not very uncommon (Thampan, 1982).

Floral biology

The male flower has six thin, yellow perianth leaves surrounding six stamens and three nectar glands at the centre. When the male flowers open, the anthers are split longitudinally releasing large quantities of yellow pollens for about 24 hours and then drop off. Pollen discharge or anthesis will continue for about 18 20 days (male phase) because of the fact that maturation of inflorescence is a progressive process starting from the upper to the lower spikelets and from top to bottom on each spikelet. The pollen yield is also a function of palm genotype. The pollen usually remains viable for about 2 9 days after it is discharged (Santos and Balingasa, 1977). The female flower or 'button' is globose and consists of six fleshy perianth leaves surrounding the pistil. The pistil is white and has three ridges which converge at the tip. When the flower is developed, these ridges split open exposing the sticky surface of the stigma which is extended as three erect teeth. Normally, the opening of female flower commences by the 21st day, but during the summer months the flowers may open even from the 18th day onwards. The female phase lasts for 4 7 days. During this phase, the receptivity of the stigma remains intact for a period starting from one or two days after opening and extends up to a maximum of three days (Rognon, 1977).

Pollination

Genetically, the dwarf palms are considered autogamous (direct self pollinating), the talls allogamous (cross pollinating) and the hybrids and a few dwarf types, particularly the green ones, capable of uniting both the types. However, overlapping of phases of two successive inflorescence is a characteristic conditioned by the interaction between genotype and environment.

Both wind and insects are considered to be the main pollinating agents in coconut palms. Among the insects, bees belonging to *Apis indica*, *A. florea* and *A. dorsata* are important. The European bee *A. mellifera* is also a recognised pollinating agent. Besides bees, other pollinating insects are ordinary housefly, small wasps and beetles.

After pollination, the unfertilised flowers turn brown and drop from the inflorescence. A number of fertilised flowers also fail to develop properly and they are shed. Since much more number of female flowers or buttons are usually produced than the palm can retain to the stage of maturity, it is not unusual to observe shedding of 50 to 70 per cent of the buttons produced. Generally, not more than 25 to 40 per cent of the female flowers reach maturity (Thampan, 1982).

12.10 Fruit Growth and Shedding of Nuts

Fruit growth

After fertilisation it takes about 11–12 months for the flower to develop in to a mature nut. The fleshy parianth leaves of the flower are at the base of the nut throughout this period. When the nut is about five months old, it attains full size and the meat begins to form as a thin layer of jelly around the inside of the endocarp or shell. When the nut is four months old, it contains maximum quantity of clear, sweet and refreshing drink known as 'coconut water'. At this stage, the sugar concentration is very low, which, however, increases to a maximum at about 7 months and during this period only the reducing sugar is present. Thereafter, sucrose appears in coconut water but the concentration of total sugar falls. In a study, it was found that the sugar content decreases from about 8·8 per cent in the 8th month to 1·4 per cent in the 12th month. The oil content in the kernel during this period increases from about 31 to 71 per cent (Kamaladevi and Velayntham, 1978).

As the fruit matures, the nut water is partially replaced by the meat. The endocarp or shell begins to harden when the nut is about 7 months old. When the meat is 11 12 months old, the shell becomes fully hardened and the meat fully formed with a brown outer testa adhering inside the endocarp. Though the fresh weight of meat is maximum during the 10th month, the weight of dried kernel or copra is the highest at the 12th month. In general, a fully matured fruit will have a composition by weight of about 35 per cent husk, 12 per cent shell, about 28 per cent meat or kernel and 25 per cent water.

Shedding of buttons and immature nuts and production of barren nuts

These are some of the important problems of coconut cultivation which adversely affect the yield to a large extent. The probable causes which may be attributed to these maladies are attack of pests and diseases, nutritional deficiencies, unfavourable soil and climatic conditions, defects in pollination and fertilisation and the limited capacity of the tree to bear fruits.

Diseases and pests

Investigations carried out in Kenya, showed that falling of buttons and immature nuts was due to infection of female flowers by fungus, *Collectotrichum* sp. (Mac Donald, 1924), while in Ceylon, Philippines and India, it was caused by *Phytophthora* sp. (Gad. 1922, 1923, 1924 ; Sundaraman and Ramakrishnan, 1924). Experiments conducted in Ceylon to determine the efficacy of spraying of Bordeaux mixture as preventive against shedding of immature nuts were, however, not very encouraging (Gad, 1923).

In Taveuni Island, the shedding of buttons was found to be largely due to the attack of a moth, (*Acritocera negligens*), a beetle (*Diocalandra taitensis*) and rats (Simmonds, 1951). In the Solomon Islands, the premature nut fall was, however, caused by a coreid bug (*Amblypelta cocophaga*) which was found to be driven out by some species of ants (O'Connor, 1950).

Nutritional deficiencies

Nutritional deficiency in soil is considered to be another factor responsible for shedding of buttons. Application of nitrogenous manures has been found to increase setting and ultimate yield. Comparative analysis of various plots in Indo-China (Vietnam) led to the conclusion that the fundamental cause of shedding was insufficient nourishment of the plant which was corrected by the application of the nitrogenous manures (Gad, 1923). In Ceylon (Sri Lanka), it was observed that fertiliser application increased the total yield by an increased production of female flowers rather than by reduction in shedding of buttons (Anon, 1947). Some workers believed that shedding of buttons was due to the weakness of the bunch stalk and lack of mechanical strength in the tissue (Child, 1950).

Unfavourable soil and climatic conditions

Investigations carried out on this problem in Kenya (MacDonald, 1924), British Solomon Islands and New Guinea (Dawyer, 1937) indicated that shedding of buttons occured not only when there was deficit of moisture but also during the wettest time of the year. According to Patel (1938), the shedding of buttons was very high during August, September and November and slightly lower during other months. He further noted that shedding of buttons was more severe on heavy soils than on lighter soils.

Defective pollination and fertilisation

Imperfect pollination or lack of pollination is considered to be another important factor for shedding of buttons. In Zanzibar, the fall of buttons was found to be due to the failure in fertilisation caused by the abortion of carpels in the female flowers (Welsford, 1926). In India, it was, however, observed that artificial pollination did not minimise shedding (Menon and Pandalai, 1960).

Formation of abscission layer

As the increase in shedding of buttons followed a period of draught, it was felt that formation of abscission layer at the place of attachment to the stalk, may perhaps, cause shedding as a result of severe draught. Child (1950) in Ceylon suggested that as all the attempts to control shedding of nuts had failed, spraying with hormones might well be tried to check its incidence. Of the several hormones tried at the then Central Coconut Research Station, Kasaragod, Kerala,

2, 4-D at 60 ppm when sprayed on female flowers at weekly intervals for a month starting just after completion of fertilisation, proved very useful and resulted in more than double the setting of buttons as compared to that of the untreated plants and increased the yield of nuts (Gangolly *et al*, 1956 ; 1957). In Zanzibar, spraying with BHC and DDT preparations proved effective in controlling the immature nut fall (Child, 1953).

Production of barren nuts

The phenomenon of the occurrence of barren nuts (without or with imperfectly developed kernel) is as ancient as the cultivation of coconut. From the detailed investigations carried out on this problem at Kasaragod, Kerala, it was revealed that in the coconut plantations certain trees produce a large number of barren nuts. The nuts are generally oblong in shape and the quantity of husk produced is very much less as compared to normal ones. The embryo in the barren nuts is mostly absent or when present, it is in varying stages of decay. Often, these nuts are seen with the shell and kernel improperly developed. Fungal infection is also, sometimes, noticed in the embryo, resulting in the decay of the kernel and loss of water inside (Anon., 1935, 1948-49). Of the different types of barren nuts met with, those with cracking of shell is relatively more common than the other types.

Several causes for this phenomenon have been advanced by the research workers. Furtado (1924) thought this phenomenon to be due to defective fertilisation resulting in malformation of embryo. Preliminary trials carried out at the then Central Coconut Research Station, Kasaragod, revealed that barrenness could be induced by keeping female flowers unfertilised indicating thereby that defective fertilisation may be one of the possible causes of barren nut production. Nutritional deficiency in the palm is also considered to be another cause of barrenness. Preliminary work done at Kasaragod to determine the possibility of reducing the incidence of barren nuts through heavy manuring with 2·722 kg ammonium sulphate, 1·814 kg of bone meal, 27·215 kg ash and 90·718 kg of green manure per tree failed to show any distinct beneficial effect (Anon., 1947). Although investigation made on the phenomenon failed to establish conclusive reasons for the occurrence of barren nuts, it is not, however, improbable that excessive bearing may be one of the causes.

12.11 Pests and Diseases

Pests

The major insect pests of the coconut palm are the rhinoceros beetle (*Oryctes rhinoceros*), the leaf eating caterpillar, (*Nephantis serinopa*), the red palm weevil (*Rhynchophorus ferrugineus*) and the root eating cockchafer (*Leucopholis coneophora*) (Anon., 1983, Thampan, 1982).

Rhinoceros beetle : This is the most serious pest which has an ubiquitous distribution. The adult beetle bores through into the unopened fronds and spathes. The affected fronds when fully open will show characteristic geometric cuts. Infestation on spathes often destroys the inflorescence and thus prevents production of nuts. The beetle breeds in a variety of materials such as decaying organic debris, farm yard manure, dead coconut stumps and logs and compost. The total duration of life cycle of this pest is about six months.

Maintenance of sanitation in coconut gardens by proper disposal of decaying organic debris is an important step in the management of this pest. Mechanical method of control is possible by extracting the beetles with beetle hooks without causing any further injury to the growing point of the palm. Filling the inner most three or four leaf axils of palms with a mixture of 5 per cent BHC dust and sand in equal proportion is an effective prophylactic measure. Three applications in April, September and December are adequate to give sufficient protection to palms in heavily infested tracts. Treatment of all the possible breeding sites of the beetle with 0·01 per cent Carbaryl is an effective method of controlling the immature stages of the pest. Powdered castor seed is boiled with water till frothing and after keeping for four days it can be used as an attractant for the beetles. The resultant increase in yield obtained due to pest control operation was 5 to 8 nuts per palm per year. Release of the exotic predator (*Platymeris laevicollis*) was found to give substantial reduction in pest infestation on the palms.

Leaf eating caterpillar : This is another serious pest in the coastal and brackish water tracts. In recent years, this pest got access into certain interior tracts as well and assumed severe proportions. The caterpillars live on the under surface of leaflets inside silken galleries and feed voraciously on the chlorophyll containing functional tissues. This affects the health of the palm adversely and results in reduction of yield. The severity of infestation by this pest will be marked during the summer months from February to June. With the onset of south-west monsoon the pest population begins to decline.

Spraying the infested palms with BHC (0·2%) or Malathion (0·05%) on the lower surface of leaves, so as to give a thorough coverage to the larval galleries, would give satisfactory control of the pest. Chemical treatment may be done only in severe outbreaks at quarterly intervals in March, June, September and December.

Mass multiplication, liberation and colonisation of indigenous and/or exotic parasites in the infested fields would control the pest population. The Eulophid pupal parasite (*Trichospilus pupivora*) and the larval Bethylid parasite (*Perisierola nephantidis*) are the most important parasites utilised for the control of this pest in India. Other useful parasites are the larval parasites of *Bracon brevicornis* and *Elasmus nephantidis* and the pupal parasites of *Brachymeria nephantidis*. The tachinid fly (*Spoggosia bezziana*) has been found to be a very good larval parasite in Sri Lanka (Perera, 1968).

Red palm weevil: This is a most dangerous pest of young coconut palms. Generally, palms of the age group 5-20 years are affected. Since the pest is a tissue borer, its detection in early stage of infection is rather difficult. The major diagnostic symptoms of red palm weevil infestation are the presence of holes, oozing out of a viscous brown fluid and extrusion of chewed up fibres through the holes, longitudinal splitting of leaf bases and wilting of inner leaves. Some times the gnawing sound produced by the grubs feeding inside will also be audible. Quite often, the infestation would become evident only when the growing point of the palm is damaged and the crown toppled.

Affected palms can be saved by injection of pyrethrin piperonyl butoxide (Pyrocone E) or Carbaryl (Sevin) at 1 per cent concentration. Ten ml. of Pyrocone E or 20 gm of 50 per cent Sevin in one litre water per palm should be introduced into the trunk through a hole above the infested portion using an auger and funnel. All the holes on the affected stem should be plugged before injection. If the pest infestation is through the crown, the insecticide suspension should be slowly poured in after clearing the crown of all affected materials. Trichlorophon or Endosulfan 0·2 per cent is also found to be effective in controlling this pest. A prophylactic treatment of filling all the leaf axils of young palms with BHC or Chlordane 5 per cent dust and sand mixture in April, September and December reduces the weevil infestation. Chemicals like Fenthion 0·2 per cent and Carbaryl 1 per cent suspension and aluminium phosphide (Phostoxin) at one and two tablets per tree are effective against the larval, pupal and adult stages of the pest (Subba Rao *et al*, 1973).

Coconut logs 50 cm long, split longitudinally and cut surfaces smeared with fresh toddy fermented with yeast and acetic acid are effective traps. Weevils thus trapped can be collected and killed.

Entry of this pest through cut ends of leaf base can be prevented by leaving a length of 120 cm of petiole while cutting leaves. Dead palms should be cut and burnt. The administration of systemic insecticides like Monocrotophos 10 ml diluted with equal quantity of water through the cut ends of functioning root have also been reported effective (Manthriratna, 1965).

Root eating cockchafer: The soil inhabiting white grubs cause damage to the roots of coconut, it also infests tuber crops like tapioca, colocasia, sweet potato, etc., grown as intercrops. The leaves of affected palms become sickly and pale yellow. In case of heavy infestation, there will be immature nut fall as well.

Tilling or deep ploughing of infested soil will reduce the pest population to a great extent. Soil application of 5 per cent Aldrin or BHC or Chlordane dust at 120 kg per hectare twice a year in April-May and August-September will control the pest. The insecticide is to be broadcast and incorporated into the soil.

The Asiatic palm weevil (*Rhynchophorus schach*), leaf beetle (*Promecotheca cumingi*), slug caterpillars (*Parasa lepida, Thosea sinensis, Contheyla rotunda*),

the scale insect (*Aspidiotus destructor*) and the termites (*Odontotermes obesus*) are the other insect pests infesting coconut in India and elsewhere.

Rat

It is a serious pest of the coconut palm in many coconut growing countries. The extent of damage caused by rats in India is estimated to be 5-10 per cent of the total production. In some countries the damage is more severe. The species common in India is the house rat (*Rattatus rattus*). In India, the burrowing rat (*Bandicota bengalensis*) is also a serious pest. The house rats enter the crown of the palm and burrow into the immature nuts and drink the water and eat the soft meat. The attacked nuts are damaged and shed. The burrowing rats bore through the root system and uproot the seedlings. They also cause serious damage to the crown of young palms. The use of traditional traps is the most common control measure against rats.

Diseases

The coconut palm is affected by a number of diseases, some of which are lethal while others gradually reduce the vigour of the palm causing severe loss in yield.

Bud rot : This disease caused by a parasitic fungus, *Phytophthora palmivora*, has been reported from all coconut growing states. It is a fatal disease affecting palms of all ages but young palms are found to be the most vulnerable. The first symptom of the disease is the yellowing of one or two young leaves surrounding the spindle. The spindle withers and droops down. The tender leaf bases and the soft tissues of the crown rot into a slimy mass of decayed material emitting a foul odour. Even after the death of the central bud, the outer leaves and bunches may continue to remain intact for several months. The disease is rampant during the monsoon when the atmospheric temperature is low and the humidity is high (Thomas, 1978).

Bordeaux paste (1 per cent) should be applied on the crown after removing the infected tissues and a thorough cleaning. The treated wound should be given a protective covering till the next normal shoot emerges. Badly affected trees which are beyond recovery should be cut and burnt. As a prophylactic measure, all the healthy palms in the vicinity of the diseased one should be sprayed with 1 per cent Bordeaux mixture.

Leaf rot : This disease, caused by *Bipolaris halodes*, *Gloeosporium* sp. and *Gliocladium roseum*, is mostly prevalent in the southern districts of Kerala and generally occurs on palms already affected by root (wilt) disease. The first symptom of the disease is blackening and shrivelling of the distal ends of the leaflets in the central spindle and in some of the younger leaves. Later, the affected portion breaks off in bits giving the infected leaves a fan like appearance. If no protective measures are taken, each new leaf of the diseased tree gets infected

and a stage is soon reached when all the leaves of the tree show disease symptoms. The reduction in leaf surface adversely affects the yield.

Spraying the leaves with 1 per cent Bordeaux mixture or any other proprietary copper fungicide such as 0·05 per cent Fytolan or organic fungicide, 0·3 per cent Dithane M 45 after removing all affected materials once in January, April, May and September, controls the disease.

Leaf blight or *Grey leaf spot* : This fungal disease caused by *Pestalotia palmarum* is common in most of the coconut growing states. The disease symptoms develop in the mature leaves of the outer whorl. Minute yellow spots encircled by greyish bands appear on the leaf surface which later become greyish white. These spots coalesce into irregular necrotic patches. Complete drying and shrivelling of the leaf blade are common when the infection is severe.

Removal of the older affected leaves and spraying the foliage with 1 per cent Bordeaux mixture will check the spread of the disease.

Mahalo or fruit rot and nut fall : Shedding of female flowers (Buttons) and immature nuts are the symptoms of the disease. Lesions appear on the young fruit or buttons near the stalk which later develop into a decay of the underlying tissues. This disease is caused by the fungus *Phytophthora* sp. The pathogen is more active during the rainy season when the atmospheric conditions are favourable for its growth.

A pre-monsoon spraying with 1 per cent Bordeaux mixture or any other effective copper fungicide as Fytolan (0·05 per cent), followed by one or two sprayings at intervals of 40 days is generally advisable.

Stem bleeding : The cause of the disease is unknown but the association of a fungus, *Thielaviopsis paradoxa* has been reported. It is believed that the physiological disorders may have a major role in the occurrence of the disease.

The typical symptom of the disease is the exudation of a reddish-brown liquid through cracks developing on the trunk. On drying the liquid turns black. The tissues around the bleeding points start decaying which later develop into a general decay of the tissues underneath the bark. Fatal instances of stem bleeding are not uncommon.

The damage of stems can be checked to a certain extent by completely removing the affected tissues using a chisel and dressing the wound with hot coal tar or Bordeaux paste.

Anab-e-roga or *Trunk and root rot* : This disease is caused by the fungus *Ganoderma lucidum.* The older leaves which start drooping and withering remain suspended around the trunk for several months before they are shed. Younger leaves remain green for sometime. The trees become barren due to the suppression of the inflorescence. The crown is reduced in size and the new leaves become smaller and yellowish in colour which finally wither as the bud decays. In certain cases, bleeding patches around the base of the trunk are also seen. A brownish

gummy juice exudes from these patches which slowly results in the death of the outer tissues of the trunk. The tree succumbs to the disease in about two years. The sporophores (fruiting body) of the fungus are not commonly met with but may sometimes be seen under the scaling bark close to the ground on diseased palms.

The disease can be kept under control by destroying the infected palms and preventing the spread of the fungus by digging isolation trenches about 40 cm wide and one metre deep, two metres away from the diseased palms. In India, use of Difolatan (100 ppm) in combination with Aureofungin has shown promising results at the early stages.

Tatipaka disease (Andhra) : Palms in the age group of 26-60 years are most susceptible to this disease. The development of an abnormally large crown, with dark green inner leaves and higher yield are the initial symptoms of disease incidence. Subsequently, the crown becomes smaller producing progressively shorter leaves. The stem begins to taper. The leaves give a fasciated appearance due to improper unfolding of leaflets. The affected trees produce smaller spadix with atrophied barren nuts. The etiology is still uncertain. Destruction of badly affected palms might prevent spread of the disease.

Thanjavur wilt : This disease was first noticed in the coastal areas of Thanjavur district following the cyclones of 1952 and 1955. It is now prevalent in all the coconut growing districts of Tamil Nadu.

Decay of root system, flaccidity of spindle leaves, browning of outer leaves, arrested fruit set and appearance of bleeding patches on the stem are the salient features of the malady. The affected palms die within 2 to 3 years. The cause of the disease is not clearly known. However, application of organic manures and irrigation could check the spread of the malady to some extent.

The yellow mottle decline (Cadang-Cadang), lethal yellowing and leaf scorch disease of unknown etiology are known to occur also in coconut.

Root wilt

This disease has been prevalent in Kerala for nearly 100 years and is believed to have made its appearance after the great floods of 1882. Recently, it has established itself almost contiguously in seven districts in Kerala and also in parts of Tamil Nadu. Out of 7,50,000 ha of coconut, nearly 30 per cent of the area is affected by this disease and the annual loss from Kerala alone is estimated around 340 million nuts.

The important visual diagnostic symptoms of the disease are abnormal bending or ribbing of the leaflets termed as 'flaccidity', and a general yellowing and marginal necrosis of the leaflets. The yield is reduced considerably on account of the disease. The nuts are smaller and the kernel is thin. The oil content of the copra is reduced. The exact cause of the malady is not known though the association of fungi, bacteria and virus have been implicated. To

reduce the loss due to the disease and to contain it to the extent possible, the following measures are recommended (Bavappa, 1983) :

(i) Removal and burning of severely diseased uneconomic palms (yielding less than 10 nuts/year).

(ii) Application of NPK fertilisers at recommended dose, magnesium sulphate at 1 kg per palm per year and organic manures.

(iii) Irrigation during summer months.

(iv) Control leaf rot which is usually noticed on root (wilt) affected palms by fungicidal sprays.

(v) Planting hybrids of Chowghat Dwarf Orange and West Coast Tall in disease affected areas.

Maintenance of optimum population of productive palms per unit area, use of precocious and high yielding planting material (CDO × WCT) and introduction of an integrated farming system are the strategies at hand for combating the disease (Thampan, 1983).

12.12 Harvesting

Coconut usually ripens in about 12 to 13 months after the opening of the inflorescence. In order to get the maximum yield of copra and oil, only fully matured nuts should be harvested. The loss of copra is 6 per cent in 11 months old nut, 16 per cent in 10 months old nut and 33 per cent in 9 months old nuts. Similarly, the reduction in the percentage of oil in 11, 10 and 9 month old nuts being 5, 15 and 33 per cent respectively. There is no appreciable difference in the yield of coir fibre obtained from 12, 11 and 10 months old nut. As fully matured nuts contain small amount of water inside, it can be recognised by shaking the nut.

The refreshing green coconut water is very popular, particularly in the eastern part of India, and a large number of coconuts are harvested in green immature stage.

Although the palm produces 12 inflorescences in one year, some of the inflorescence may fail to develop into fruits. The number of bunches available is therefore, normally less than 12. The frequency of harvest varies in different coconut growing countries and also in different regions in a country. In the West Coast, 6 to 12 harvests are the usual practice. In many areas of Kerala, harvesting is done at 45 days' interval during the summer months and at 60 days' interval during the rainy season. In some other states of India, harvesting is done twice a year. In the Philippines and Sri Lanka coconut is harvested 6 times a year.

In India, the harvesting is done by climbing the tree. The climber often uses a small ladder. After climbing to the top of the ladder he uses a rope ring round the feet for climbing the rest of the tree. On reaching the crown, the climber examines the stage of maturity of the nut and cuts down the mature bunches.

The climber also removes dry leaves, sheaths and spathes and cleans the crown at the time of harvesting. In Sri Lanka, harvesting is done from the ground with the help of a knife attached to a long bamboo pole. In Malaysia and Thailand, trained monkeys are also used for harvesting. In parts of Africa and the Pacific Islands, where experienced climbers are not always available, the nut are allowed to fall from the bunches and the fallen nuts are collected (Thampan, 1982).

12.13 Yield

The yield of coconut palm is influenced by the agro-climatic conditions, as well as cultural practices such as manuring, irrigation, cropping system, and pest and disease control in addition to the inherent characteristics of the palm. Hence, the yield is highly variable. Nevertheless, varietal differences in yielding ability have been well recognised. The tall varieties of coconut produce on an average 60-80 nuts per year. Some tall varieties like Laccadive Ordinary and Laccadive Micro yield heavily with 120 and 180 nuts per year, respectively while the varieties Andaman Ordinary and Kappadam produce 50 to 60 nuts annually.

Among the dwarf varieties, though the Dwarf Green palms are reported to produce a mean yield of about 70 nuts, palms yielding more than 120 nuts per year are not uncommon. Dwarf Orange palms are known to yield better than Dwarf Green with a mean nut yield of about 90 per year. Malayan Dwarf palms are heavy bearers, producing on an average 120 nuts annually. Gangabondam, another dwarf type gives 65 nuts per palm annually. The hybrids of Dwarf×Tall and Tall×Dwarf are also better yielders bearing of 75-90 nuts per year. But the yield in hybrids is highly unstable and is dependent on care and management.

Inherent yield potentials of palms in the garden

In any garden there will be trees of different yield capacities. Generally, there are three main groups, viz., poor yielders (40 nuts and below/year), medium yielders (41-80 nuts/year) and heavy yielders (more than 80 nuts/year). Usually the heavy yielders comprise only a small percentage of the total palms in a garden. However, the heavy and medium yielders are responsible for the major share of the total production (Jack, 1925 ; Murray, 1950). The results of an investigation carried out in a plantation consisting of about 1400 trees are summarised below :

TABLE 15. PROPORTION OF TREES OF DIFFERENT YIELD GROUPS IN A PLANTATOIN

Yield group (mean annual yield)	Percentage of trees falling in the group	Percentage of total yield accounted for by the group
Poor (40 nuts and below)	32·0	17·3
Medium (41 to 80 nuts)	59·4	66·9
High (81 and above)	8·6	15·8
	100·00	100·00

Thus, high yielders which formed only 8·6 per cent of the population accounted for 15·8 per cent of the total crop, while poor yielders which formed 32·0 per cent of the trees could account for only 17·3 per cent of the total crop. The results of a detailed study of the characters associated with yield in a set of heavy, medium and poor bearers growing in one compact block and receiving identical treatment are summarised in Table 16.

TABLE 16. CHARACTERS ASSOCIATED WITH YIELD IN TREES OF DIFFERENT YIELD GROUPS

Characters	Heavy bearers (more than 81 nuts/year)	Medium bearers (41-80 nuts/year)	Poor bearers (40 and below)
Annual yield	99·8	58·8	25·0
No. of spadices produced	13·4	12·8	11·4
No. of female flowers produced	370	263	135
Percentage of fruit set	26·9	22·3	18·5
No. of female flower/bunch	27·6	20·5	11·8
Nuts/bunch	7·4	4·6	2·2

It is seen that all the yield contributing characters showed higher values in high yielding palms as compared to low yielding palms (Patel, 1938).

Seasonal fluctuations in yield

In India, the hot weather season usually accounts for more than a third of the annual crop (Krishna Marar and Pandalai, 1959). The yield of copra per nut also varies in different months (Anon, 1962). The seasonal fluctuations in nut and copra yield are shown in Tables 17 and 18.

TABLE 17. SEASONAL FLUCTUATIONS IN NUT YIELD

Quarter	Percentage of the annual yield
March-May	35·6
June-August	25·7
September-November	18·6
December-February	20·1

TABLE 18. YIELD OF COPRA (1000 Nuts)

Month	Weight of copra/1000 nuts (kg)
January	163
February	181
March	178
April	176
May	179
June	165
July	152
August	139
September	147
October	148
November	155
December	158

Variation in yield in different areas

The average yield in India in terms of number of nuts produced per palm is at par with that of the other coconut growing countries. However, considerable variations exist among the states. In Tables 19 and 20 are given the data on the yield of nuts in different coconut growing countries and in the states of India.

TABLE 19. THE AVERAGE YIELD IN DIFFERENT COCONUT GROWING COUNTRIES

Name of the country	Yield/ha (Nos.)
Fiji	2,319
India	5,346
Indonesia	3,870
Malaysia	4,065
Papua New Guinea	2,935
Philippines	3,835
Sri Lanka	4,573
Thailand	1,339
Zanzibar	3,143
Western Samoa	5,063

TABLE 20. YIELD OF NUTS IN DIFFERENT STATES OF INDIA

States	Yield/ha (Nos.)
Andaman and Nicobar Islands	3,220
Andhra Pradesh	4,136
Assam	6,327
Goa, Daman, Diu	4,599
Karnataka	5,241
Kerala	4,815
Lakshadweep Islands	7,786
Maharashtra	5,366
Orissa	4,368
Pondicherry	9,438
Tamil Nadu	9,465
Tripura	1,375

12.14 Storage

After harvest, the nuts are usually stored in heaps under shade for few days. Storage of nut is considered necessary for the following reasons :

(i) Husking becomes easier

(ii) The moisture content of the meat decreases and its thickness increases. The yields of copra and oil also increase.

(iii) The quality of copra also improves.

It has been reported that storage of harvested nuts is beneficial only if the nuts are fully ripe. Though storage of comparatively immature nuts increases the yield of copra per nut, such nuts are easily spoiled on storage.

12.15 Breeding and Varietal Improvement

Evolving superior high yielding varieties of coconut by breeding does not appear to have received the attention it deserves. Although breeding offers considerable scope, the age to which the coconuts grow, its height, the long interval between generations, the absence of genetical purity in the material available for hybridisation, the long period of experimentation, necessary before a cross progeny could be declared superior, were probably the factors which had been responsible for the slow rate of progress. The methods for coconut improvement consists of introduction of better varieties, artificial self-pollination and selection from among the selfed lines, hybridisation and selection, and also mass selection (Dawyer, 1938).

Introduction

The introduction of promising varieties from different parts of the world enjoying like climate (homoclime) has been acknowledged as a profitable method of crop improvement (Dawyer, 1938 ; Satyabalan, 1955).

The different varieties of coconut from Ceylon, Indo-China (Vietnam), New Guinea, Cochin China (Vietnam), Java, Siam (Indonesia) Thailand, the Philippines, Fiji, Laccadives, etc., were introduced by the then Madras Agriculture Department. The former Cochin Department of Agriculture had also introduced varieties from Malaya, Sea Island and the Philippines, etc., and more recently varieties from Solomon Islands. Borneo, Seychelles, Panama, East Africa, West Indies, Andamans, etc., have been introduced.

TABLE 21. PERFORMANCE OF EXOTIC TALLS AT NILESHWAR (INDIA)

Variety	Oil percentage	Yield of nuts	Mean copra per nut (gm)	Annual out-turn of copra per palm (kg)
Java	70·2	65	185·5	12·0
New Guinea	65·6	124	202·2	25·0
Cochin China	66·2	77	226·6	17·4
Philippines	69·0	94	249·7	23·4
Laccadive Ordinary	72·0	120	160·0	19·2
Laccadive Micro	75·0	140	81·0	11·3
West Coast Tall	70·6	88	147·4	12·9

Though the oil content of the exotic types is generally low, it is more than compensated by the much higher annual copra out-turn per tree. It is, however not known whether the performance of these types will be similar under different agro-climatic conditions prevalent in this country (Nambiar, 1979). This method of improvement of coconut through introduction suffers on account of the poor adaptability of exotic types to the wide range of agro-climatic conditions encountered in India as also the chances of getting already available varieties duplicated.

Self-pollination

The role of self-fertilisation in breeding work on coconuts has been much stressed (Harland, 1957). Since the coconut plant is mostly cross-fertilised, it has accumulated a large number of deleterious recessive genes and these would come to light on selfing. Deleterious recessives would also occur in paired crosses since the parents might be heterozygous for the same recessive gene. But the experiment in this direction at Kasaragod (Kerala) revealed that the selfed progenies were the least vigorous, while seedlings from natural and crosspollinated nuts were definitely superior in vigour (Patel, 1937). However, these results

cannot be true for all cases as it was seen that inbreeding depression does not appear to be important in coconut and hence may be attributable to the fact that different varieties will respond to selfing in different ways and to different extents.

Hybridisation

The emphasis on hybridisation or controlled cross-breeding for coconut improvement has become greater in recent years (Patel, 1937 ; Satyabalan, 1956 ; Liyanage, 1956 ; Harland, 1957). The possibility of making hybrids by controlled pollination when both male and female parents are known, is designated as a 'paired cross', which formed the basis of a new method of tree breeding. As some of the high yielding paired crosses have given a yield more than twice the average, resowing of proved high yielding paired crosses, between the best of the paired crosses have given still further increase in yield, so that with heavy manuring it reached a level about double that of the original unselected type. Breeding in coconuts differs from other annuals in that once a pair of trees has been established for crossing to give uniformly high yielding offsprings when crossed, that pair can be subjected to further crossing, for the production of seedlings, which after screening for undesirable seedling characters, can be used for commercial distribution and trial. The necessity for determining the prepotent maternal transmitters, which in spite of having been indiscriminately pollinated by miscellaneous males, are sufficiently possessed of dominant yield factors to ensure that their offsprings are also high yielding. Once the maternal transmitter is identified, it can continuously be used in paired crosses, self-fertilisation and as male parent in extensive crosses with high yielding mother palms (Harland, 1957). The process of identifying male transmitters can be speeded up by the use of dwarf palms as female since they are largely self-pollinated and are reasonably homogeneous. The following combinations have been attempted in cross-breeding of coconuts :

(A) Dwarf × Dwarf
(B) Tall × Dwarf
  (i) Tall × Dwarf
  (ii) Dwarf × Tall
(C) Tall × Tall

Tall × Dwarf hybrids (T × D) : The different forms of Dwarf variety used as male parents are Dwarf Orange, Dwarf Green, Gangabondam and Malayan Dwarf Yellow. Such hybrids possess desirable characters as precocity in bearing, ability to give the normal yield even in the first year of bearing and higher productivity than any of the parental types. All the hybrids of Tall × Dwarf (Green), Tall × Dwarf (Orange) and Tall × Gangabondam exhibited heterosis in the weight of the husked nut, nut water and kernel content (Satyabalan *et al*, 1970). Among the male parents, Dwarf Orange and Gangabondam proved to

be the best for the production of economic hybrids with the West Coast Tall with the exception at Tamil Nadu, where the Dwarf Green proved superior followed by the Malayan Dwarf (Yellow) in all the crosses with the local tall types (Ramachandran *et al*, 1974).

While recognising the desirable economic characteristics of T×D hybrids, it also becomes all the more important to look into the major undesirable traits exhibited by these hybrids. In a few instances, it has been observed that such hybrid planting materials supplied to the growers, showed predominantly dwarfish traits with manifestation of alternate bearing tendency, bunch buckling and less tolerance to drought under field conditions. Under certain conditions, the hybrids after giving initial good yields, failed to maintain consistency in yield later. Similarly, unlike the tall variety, the hybrid palms are easily susceptible to soil moisture fluctuations, resulting in shedding of buttons and drooping of leaves during summer. While the local talls produce satisfactory yields under average management conditions, the hybrids express their full production potential only under best management conditions.

Dwarf×Tall hybrids (D×T) : The distinct advantage of this hybrid over T×D is that it could be produced on a large-scale either by permitting natural pollination of the emasculated inflorescences of the dwarf with the pollen of the tall palms standing nearby or by resorting to assisted pollination with the pollen collected from selected talls growing elsewhere. The use of Dwarf Yellow, Orange or Red as female parents has an added advantage that the hybrids can readily be distinguished on the basis of petiole colour. Because yellow, orange or red are recessive to brown and green pigments, the hybrids will exhibit a greenish brown or brownish petiole depending on the colour of the talls used in the crossing.

The Dwarf×Tall hybrid is more vigorous than either of the parents and is a prolific yielder. It comes to bearing in four to five years after planting and outyields the ordinary tall. The nut and copra characters are superior to those of the dwarf and are more or less similar to that of the talls. An annual production of as much as 25 kg of copra per palm has been recorded in some combinations of Dwarf Orange and West Coast Tall. The commercial possibilities of the Dwarf×Tall hybrids have been emphasised and an yield level of 5 tonnes of copra per hectare has been recorded for the hybrid progenies of Malayan Dwarf and West African Tall. The Malayan Dwarf has proved to be resistant to the lethal yellowing disease. The Dwarf×Tall hybrids involving Malayan Dwarf and Panama Tall have also been found to inherit sufficient immunity from diseases and capacity for high yield. In India, Chowghat Dwarf Orange is commonly used as the seed parent in the D×T hybrid seed gardens.

Tall×Tall hybrids (T×T) : These hybrids are produced by the intervarietal hybridisation of the Tall variety under controlled conditions. For the large scale production of T×T hybrids isolated seed gardens have been established

in Sri Lanka and India. Though late in bearing, the yield potential of such hybrids is very much comparable to that of intervarietal hybrids, particularly after the first 10 to 15 years of bearing.

The survey made on the performance of coconut varieties and hybrids in Kerala indicated that among the T×D and D×T hybrids, the latter was definitely superior to the former (Satyabalan, 1982). Under identical conditions D×T gave higher yield than T×D or West Coast Tall. Though the pre-bearing period of D×T was slightly more than T×D, tree to tree variation was not as pronounced as T×D (Anon., 1979).

In Ivory Coast, Malayan Dwarf Yellow palms are reported to give a high percentage of hybrids when crossed with West African Tall. At Nileshwar, attempt to combine the high female flower production of Spicata with the high setting percentage of West Coast Tall was however, not successful (Anon., 1977).

Mass selection

In perennial seed propagated crops like coconut, the 'maternal line selection' on which attention is paid only to the female parent formed the standard practice from very early times. Immediate improvement of the coconut lay in the direction of seed selection (Mendiola, 1926). In the absence of prolonged scientific breeding on coconut, the method of selection, if carefully performed, should produce good results but the choice of the parent tree was speculative for although the character of female parent could be ascertained. Yet because of its unknown male parent, variation in the offspring was likely to occur to some degree. But although this method of selection was not likely to produce trees true to type, it was the only practical method for the planter to adopt and the result obtained so far have fully justified the adoption of this procedure (Jack, 1930). However, there are opinions opposed to these ideas (Harland, 1957). Under the present strategy of maintenance of optimum population of productive palms in a unit area at all times rather than unsuccessfully attempting to ensure genetical purity in a garden, this method of mass selection may be a more practical feasibility.

Earlier studies made by Ninan and Pankajakshan (1961) and Ninan *et al*, (1964) indicated that on the basis of seedling performance it is possible to isolate high yielders which yield superior progenies as the differences in growth rate and vigour of seedlings between families were highly significant in comparison with the variations within the families. Satyabalan *et al*, (1975) reported on the possibility of identifying prepotent palms based on certain seedling characters (collar girth and leaf production) of progenies recorded from fifth month after germination. Satyabalan and Mathew (1976) further observed that the seedlings raised from the nuts of prepotent palms, were more vigorus than those of other palms, irrespective of the month of harvesting and germination.

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13

LITCHI

S. C. MAITI

The litchi (*Litchi chinensis* Sonn.) is a delicious, juicy fruit of excellent quality. The translucent, flavoured aril or edible flesh of the litchi is liked very much as a table fruit in India, while in China and Japan it is prized in fresh, dried or canned state. The litchi usually comes to the market in May and early June when very few fresh fruits are available in India.

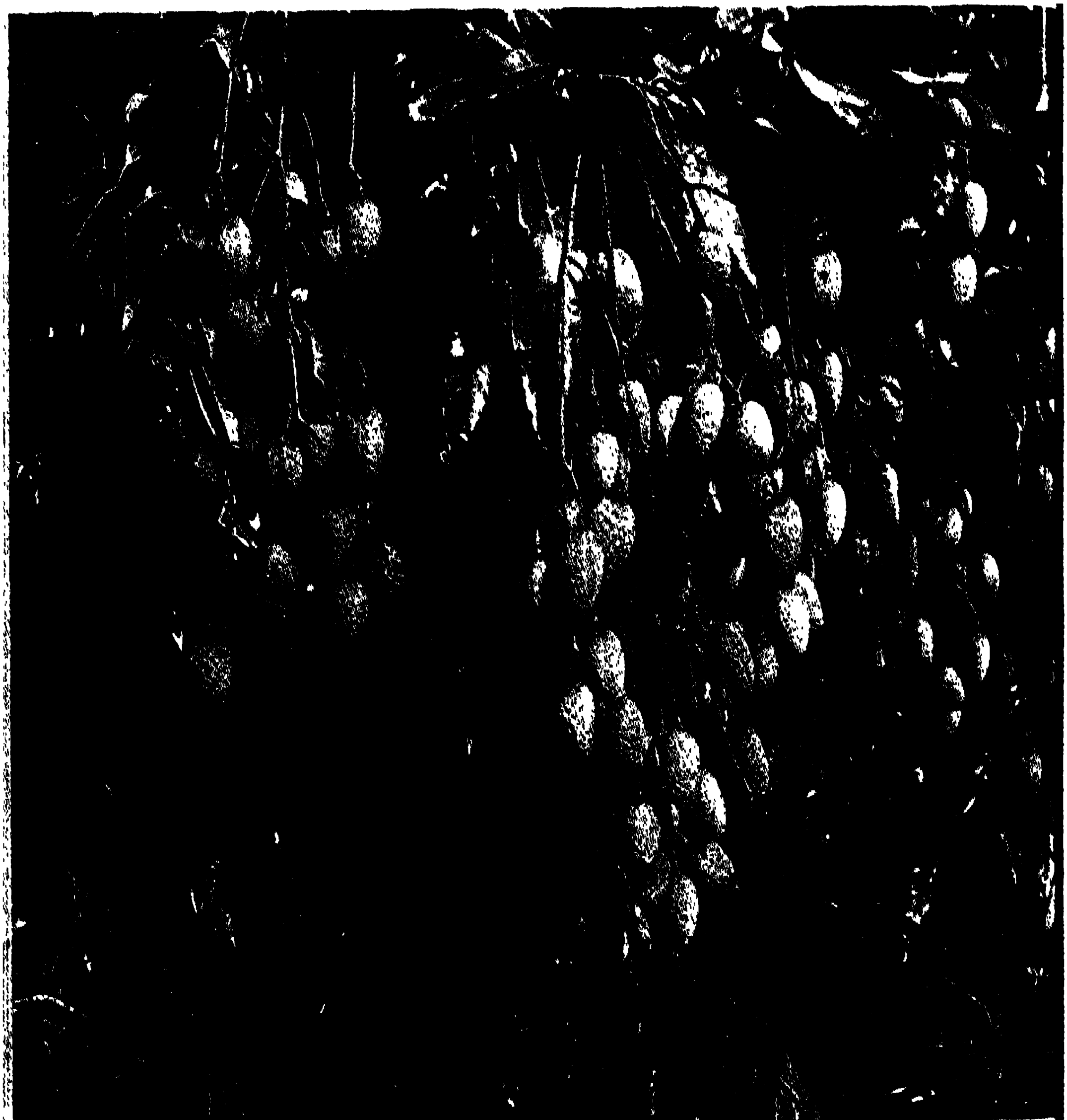
13.1 Composition and Uses

The food value of litchi mainly lies in its sugar content which again varies due to varieties and climate. The sugar content in different varieties ranges from 6·74 to 13·86 per cent in India (Singh and Singh, 1954); 12 to 15 per cent in Florida and 11·8 to 20·6 per cent in Hawaii (Miller and Bazore, 1945). Besides sugar, litchi contains protein 0·7 per cent, fat 0·3 per cent, minerals 0·7 per cent (particularly calcium and phosphorus) and vitamin C (64 mg/100 gm pulp) A, B_1 and B_2. The litchi makes an excellent canned fruit. A highly flavoured squash is also prepared from the inferior fruits which is liked by many during the summer months. Various other products such as pickles, preserves and wine are also made from litchi in China. Dried litchi commonly known as 'litchi nut' is very popular among the Chinese living all over the world. The Chinese use the leaves for making poultices, the seeds as anodyne for the skin and flowers, bark and roots for making decoctions for throat gargle.

13.2 Origin and Distribution

It is indigenous to southern China, particularly the provinces of Kwangtung and Fukien. The spread of litchi from China to other parts of the world was rather slow probably due to the exacting soil and climatic requirements of this fruit as well as very short life span of its seeds. The litchi had reached the West

A litchi tree in bearing



Bunches of litchi

Indies by 1775, South Africa in 1869, the Hawaii Islands by 1873 and Florida in 1883. Other countries where it has spread are Vietnam, Indonesia, southern Japan, Formosa, Australia, Newzealand, Brazil, etc. Litchi reached India through Burma and was first introduced in Bengal about the end of the 17th century. During the last two hundred years, it was spread further into other parts of India.

13.3 Species and Varieties

Species

Litchi belongs to the family Sapindaceae and sub-family Nepheleae which has about 125 genera and more than 1000 species. Only few members of this family are of horticultural importance. Other members of the sub-family are longan (*Euphoria longana*) 'anshphal', which grows mostly wild in Western Ghat, Bengal and Assam at elevations up to 1600 metres, bears inferior fruits of smaller size suitable for canned products and Rambutan (*Nephelium lappaceum*) bears fruits of good quality which are considered even superior to those of litchi by some people. These two plants can also be used as a rootstock for litchi.

The genus *Litchi* has two species, *Litchi philippinensis* and *Litchi chinensis* (*Nephelium litchi* Camb). The former is a wild plant grown largely in the Philippines. This species is not of commercial importance except being used as a rootstock.

The litchi trees are medium to large, much branched round-topped, handsome evergreen, reaching up to 11 metres or more in height. The leaves are compound consisting of 4–7 leaflets each, about 7–10 cm in length, glossy dark green above and greyish green on the under surface. The bark is greyish brown and rough. The inflorescence is a compound raceme developing both from terminal and axillary buds. Flowers are unisexual, bisexual or intermediate. The flowers of different sexes on the panicles do not open simultaneously. They are found to open in different flushes.

The mature litchi fruits which are one-seeded nuts, usually develop in bunches and vary in shape and size according to variety. The fruits tend to be 2·5 to 3·5 cm in diameter and usually oval in shape. The pericarp is papillate like strawberry and turns pinkish red when the fruit is ripe. The aril or edible portion in litchi which separates easily, lies under the pericarp and completely surrounds the seeds. It is fleshy, succulent, transluscent, pearly white and soft in texture. The blend of sugars and acids in the aril makes it one of the most delicious fruits.

Varieties

Many named and carefully described varieties of the litchi are grown in China. Groff (1921) listed 49 varieties of Kwangtung and stated that about 15 of these are grown commercially. Though a large number of litchi varieties are grown in

different parts of India, most of them are not well established. The same variety may be known under different names in different places and these tend to be deceptive. In Bihar, which has the largest area under litchi in India, the important varieties are China, Deshi, Dehra Rose, Purbi, Bedana, McLean and Muzaffarpur. The important varieties grown in western Uttar Pradesh including Dehra Dun and Punjab and Haryana are Seedless Early, Seedless Late, Early Large Red, Late Large Red, Calcutta, Rose Scented, Khatti and Gulabi. The varieties recommended for growing in the Punjab and Haryana are Saharanpur, Dehra Dun, Calcutta, Muzaffarpur, Seedless Late and Rose Scented. Among the eight varieties, Muzaffarpur, China, Deshi, Purbi, Elachi Early, Elachi Late, Bombai and Kasba, tried in West Bengal, Bombai, Elachi Early, Elachi Late and China are considered important both for quality and yield. The characteristics of the important litchi varieties grown in India are given below.

Muzaffarpur : It is one of the important litchi varieties mainly grown in Bihar and its adjacent states. This variety bears profusely. The fruits are deep orange to pink and are less prone to splitting. The fruits of this variety generally mature in the first week of May in eastern India, while it ripens in the middle of June in North India. It yields around 80 to 100 kg per tree. Average weight of fruit is 20 gm, pulp sweet, tough, moderately juicy, good flavour, pulp : seed ratio 4·78 : 1 ; seed weight 2·9 gm, 18 per cent TSS and 0·48 per cent acidity.

Saharanpur : This is an early variety and a heavy bearer. The fruits of this variety are large, heart shaped and deep orange to pink in colour. The fruits of this variety mainly ripen in the first week of June. The plant and fruit characters of this variety resemble those of Early Large Red and Pinjore Common and is considered to be a synonym of these varieties.

Dehra Dun : This variety is mainly grown in Uttar Pradesh and nearby states. It is a medium to high yielding variety bearing fruits after 5th year of planting. Trees are medium in vigour, attaining a height of 5 m and spread of 7 m when full grown. Fruits are obliquely heart shaped to conical, bright rose-pink in colour, average weight 18 gm and usually ripen in the second week of June. Pulp is greyish white in colour, soft, moderately juicy, sweet, TSS 17 per cent, sugar 10·41 per cent, acid 0·44 per cent, pulp : seed ratio 3·75 : 1 ; seed weight 3·6 gm. The fruit is susceptible to sunburn and cracking.

Calcutta : This variety has proved very successful for growing in comparatively hot and dry areas. The trees of this variety are poor in growth attaining an average height of 4 m and 6 m spread. This is a heavy bearing variety yielding 80 to 100 kg fruits which ripen in the last week of June. Fruits are lopsided to oblong, deep carmine red in colour, average weight 22 gm. Pulp is dirty creamy white, soft, juicy, very sweet, flavour agreeable, TSS 18·7 per cent, sugar 11 per cent, acid 0·43 per cent, pulp : seed ratio 4·34 : 1 ; seed bolo, pointed at apex and average weight 3·4 gm. The fruit is less susceptible to sunburn and cracking.

Rose Scented : This is one of the important litchi varieties grown in India. The fruits have distinct rose aroma and hence called rose scented. The trees are vigorous and attain an average height of 7·6 m and 8·2 m spread. This is a medium yielding variety producing 80 to 90 kg fruits per tree which ripen from the second to third week of June. Fruits are mostly globosely heart shaped, deep rose-pink in colour, average weight 15·2 gm, pulp greyish white, soft, very sweet, rose flavoured, sugar 12·79 per cent, acid 0·33 per cent, pulp : seed ratio 6·40 : 1 : seed small, smooth and shining, round ovate, average weight 2·07 gm. Fruits are moderately susceptible to sunburn and cracking.

Seedless Late : This is a deceptive name. It does not mean that the fruits of this variety is completely devoid of seed. The seeds in the fruits are rather shrivelled and the proportion of flesh is relatively high. The trees are very vigorous and attain an average height of 7·5 m and spread of 10 m but are not regular bearer. The yield is 40 kg per tree in a lean year and 80 to 100 kg in a heavy year. Fruits usually ripen in the third week of June. These are mostly conical and in a few cases ovate in shape, bright brick red in colour, average weight 29 gm. Pulp is creamy white, soft, juicy, TSS 18 per cent, sugar 13·8 per cent, acid 0·44 per cent, pulp : seed ratio 28·09 : 1 ; seed very small shrunken, glabrous, chocolate in colour, average weight 0·85 gm. Fruits are moderately susceptible to cracking.

China : This is the most excellent variety of litchi so far grown in West Bengal. The trees of this variety are semi-dwarf with leaves relatively small. This is not a regular bearing variety. The yield varies from 60 to 70 kg fruits per tree which ripen from the second to third week of May. Fruits are mostly globose, a mixture of nasturtium red and marigold orange in colour, average weight 25 gm. Pulp is creamy white, very sweet, soft, juicy, flavour pleasant, TSS 18 per cent, sugar 12 per cent, acid 0·35 per cent, pulp : seed ratio 14 : 1 ; seed relatively small, smooth, shining, average weight 1·5 gm. Fruits are less susceptible to sunburn and cracking.

Bombai : This is the most important commercial variety of West Bengal. The trees are vigorous and attain an average height of 6 to 7 m and spread 7 to 8 m and bear fruits regularly in large bunches. The yield of fruit varies from 80 to 90 kg per tree which ripen from the first to second week of May. Fruits are mostly heart shaped and each fruit has another tiny underdeveloped fruit attached to the fruit stalk, as in the case of the Chinese variety Home-shiuchi. On ripening the tubercles turn carmine red and interspaces uranium green in colour. Average weight of fruit varies from 15 to 20 gm. Pulp is greyish white, soft, juicy, sweet, flavour pleasant, TSS 17 per cent, sugar 11·0 per cent, acid 0·45 per cent, pulp : seed ratio 4·5 to 5·5 : 1 ; seed big, elongated, smooth, shining, average weight 2·5 to 3·5 gm and good for canning.

Elachi : This is also an important variety of West Bengal which has a bright prospect for commercialisation. The trees are moderately vigorous, attaining an average height of 5 to 6 m and spread 6·7 m and bear fruits almost regularly. The yield varies from 50 to 60 kg fruits per tree which usually ripen in the first week of June. Fruits are mostly conical, a mixture of nasturtium red and marigold orange in colour, average weight 12 to 15 gm. Pulp is creamy white in colour, sweet, soft, juicy, flavour agreeable, TSS 18 per cent, sugar 11·5 per cent, acid 0·45 per cent, pulp : seed ratio 6·91 : 1, seed relatively small, shining, average weight 1·5 to 2·0 gm. Fruits are less susceptible to sunburn and cracking.

13.4 Soil and Climate

Soil

The litchi grows under a wide variety of soils provided these are well-drained. But it does best in a deep, well-drained loam rich in organic matter. It should be ensured that the soils do not have a hard pan within 2·5 metres from the surface. It is reported that the litchi trees make better shoot and root growth on slightly acidic soils than on neutral or slightly alkaline soils (Coville, 1921 ; Marloth, 1947). In acidic soils the roots are covered with tubercles containing mycorrhizal fungi which grow on the roots of the litchi to the mutual benefit of the fungus and the plant. However, in Bihar, the soils of the best litchi growing areas contain up to 30 per cent lime (Vyas, 1938) indicating thereby that in regions where lime is deficient, it may be advantageous to add it to the soil. But it does not mean that litchi can be grown in alkaline soils and, in fact, it has failed on alkaline soils of Israel. The other important aspect for consideration is the water table which should be at least 125 cm deep. The litchi roots can stand immersion for a considerable length of time provided that the water is flowing. In no way it can stand stagnant water as it causes root decay.

Climate

Litchi, being a subtropical fruit, thrives best under moist subtropical climate. Frost in winter and dry heat in summer are limiting factors for its successful cultivation. Under these conditions the tree makes poor growth and fruit cracking is a very serious problem. The young trees require protection against frost and hot desiccating winds for several years till they are firmly established. The varieties show differences in their frost resistance. When the trees are dormant, they are not as susceptible to frost as those in active growth. So, an early frost is less dangerous than a late frost. Seasonal variations in temperature are necessary for proper fruiting. The temperature should not go beyond 40·5 °C in summer and below the freezing point in winter. In southern China, litchi is grown with

an annual rainfall of 150 cm and humidity between 69 and 84 per cent. But high rainfall is by no means absolutely essential, if irrigation facility is available. In western Uttar Pradesh, where annual rainfall is not more than 89 cm, litchi grows successfully with artificial irrigation. Prolonged rain is not desirable, especially at the time of flowering, when it interferes with pollination. Alternate spells of rain and dry heat in summer cause fruit splitting and drop. The split fruits rot quickly and are not fit for marketing. The litchi usually likes low elevations but can be grown up to an altitude of 800 metres with varying degrees of success.

13.5 Area and Distribution

In 1955-56, the total area under litchi in India was 9701 hectares which increased to 11410 hectares in 1965-66 and thus ranked second in the world in respect of area and production. The bulk of this area consisting of 8380 hectares lies in North Bihar (Muzaffarpur district), 1640 hectares in West Bengal (Murshidabad, Nadia, Hooghly and 24-Parganas districts), 620 hectares in districts of Uttar Pradesh, 210 hectares in Punjab (Gurudaspur, Pathankot and Panjore), 200 hectares each in Assam and Tripura and 160 hectares in Orissa. At present the area under litchi constitutes only about 0·75 per cent of the total area under fruits in India. There is ample scope for further extension of area under this fruit in the foothill regions of Punjab, Uttar Pradesh, and in Bihar and West Bengal.

13.6 Propagation

Seed propagation

Litchi can be propagated both by seed and by vegetative means. But seed propagation is not advocated as the litchi trees raised from seed take about 7 to 12 years to come to bearing, normally do not produce true-to-type and often yield fruits of inferior quality. Moreover, the litchi seeds lose their viability within 4 to 5 days after removal from the fruit. Seed propagation may, however, be recommended for raising rootstocks. In that case the seeds should not be allowed to become dry but should be sown fresh just after extraction. These may be kept viable for about two months by leaving the seeds in the fruits or keeping them in moist packing material. Litchi, therefore, is usually propagated vegetatively.

Vegetative propagation

Layering is the common method of propagating litchi in most parts of the world, but grafting, budding and also cutting have been reported to be successful.

Cutting

Soft wood cuttings may also be made to root with bottom heat and carefully controlled condition. Propagation of litchi from cuttings has been reported by many workers. Sen (1941) recorded rooting in cutting from two-year-old shoots by treating with IBA. In Florida, Ochse (1953) obtained high percentage of rooting in cuttings from April-May flush by maintaining a very high humidity in the propagation chamber. Sen *et al*, (1967) reported remarkable success in rooting from ringed shoots treated with IBA under mist. Beneficial effect of intermittent mist and IBA treatment on root formation in green wood cuttings of litchi was also noted by Bhandary and Shivashankar (1970).

Layering

Air-layering or marcottage or gootee is the most widely accepted method for propagation of litchi on a commercial scale. The best season for its operation is the beginning of monsoon, i.e., June-July, though it can be extended further up to August (Vyas, 1938 : Roy, 1952).

A terminal branch 45 to 60 cm in length is selected for air-layering. A ring of bark about 2·5 cm in length is removed from the branch where it is about 1·25 cm in thickness. The cambium layer is then rubbed off completely from the exposed wood. A rooting media consisting of two parts soil, one part sand and one part leaf mould or cowdung manure or sphagnum moss properly soaked in water is used in the form of a ball. A layer of moist sphagnum moss is often placed on the rooting media to ensure supply of moisture and facilitates branching of roots. The rooting media is placed on the ringed portion covering about 2 cm from the upper end of the ring. A piece of polythene of convenient size (20 cm × 25 cm) is wrapped around the rooting media and tied properly at both ends. Within 40 to 60 days after layering the roots develop from the upper end of the ring and are found through the polythene film. When adequate root system is found to develop the layer is removed by giving sharp cut about 5 cm below the lower end of the ring, prefarably at 2-3 stages. Marked improvement in root formation in air-layer was reported by Sen and Bose (1966) by treatment with 5000 ppm IBA in lanolin at the upper end of the ring. Care should be taken to ensure that there is a proper balance of the top with the newly developed root system. If necessary, the excess branches and leaves should be removed to achieve this balance. The rooted layers are then kept in partial shade in the nursery bed and they will be ready for planting during the next monsoon.

Budding

Budding and grafting, though originally tried in China, have met with some success in Hawaii and the Philippines. Nelson (1955) reported success in chip and shield budding and veneer grafting in Florida using scion wood from vigorous flushes of terminal growth which still retained some green colour and had

prominent axillary buds. The seedlings of longan though showed a great promise for being a suitable stock, were later discarded because the trees budded or grafted on them either died soon or failed to produce good yield. Litchi seedlings may, however, be used as successful stock.

Grafting

Splice grafting : A method of splice grafting litchi was developed in South Africa with considerable success. Litchi seedlings, 18 months old and grown in containers were used as stocks. A slant cut is first made on the stem of the stock, about 30 cm above the ground, retaining as many leaves as possible. The scion is taken from a young branch, ringed three weeks prior to grafting. The scion wood is then completely defoliated and a slant cut, corresponding to that of the stock is made at a point where the wood is as thick as the stock. The stock and the scion are united in their respective cut ends and wrapped with plastic strips including the whole of the scion wood. When the buds start to swell the plastic strip is slit just above a bud which will then sprout.

Inarching : Propagation of litchi by inarching has also been tried by the Chinese. It is very tedious and time-consuming method and takes several months before an inarched plant is severed from the mother plant. At Kallar and Burliar at the foot of the Nilgiris in South India up to 30 per cent success has been obtained by inarching litchi on longan. Longan as a rootstock gives quick growth but the bearing is uncertain.

13.7 Cultivation

Windbreak

Hot and desiccating winds in summer and cold winds in winter adversely affect the growth of litchi. So, for proper establishment of a litchi plantation, a suitable wind break should be planted at the orchard boundary and it should be at right angle to the direction of the prevailing winds. A row of tall-growing trees such as seedling mango, jamun, eucalyptus, arjun (*Terminalia arjuna*), simul (*Bombax malabaricum*) alternating with low headed trees, such as mulberry and neem are planted two to three years before planting of litchi in the orchard.

Preparation of land and planting

First, the land should be cleared of all the bushes and other wild vegetation. Depression and other uneven spots should be levelled. After this, the land should be ploughed with a disc plough and then with a harrow. If possible, a green manure crop such as dhaincha (*Sesbania aculeata*), sunnhemp (*Crotalaria juncea*), etc., may be grown and incorporated into the soil in order to improve the physical condition of the soil and to increase its fertility as well.

Planting system

The trees may be planted according to the square system or hexagonal system. The former method is commonly followed as all the cultural operations can be performed more conveniently. Though the hexagonal system accommodates about 15 per cent more trees than the square system, it is not usually followed as the plants become crowded after a few years and cultural operations cannot be performed properly.

Planting distance

Litchi trees are usually planted 10 metres apart both ways, i.e., in rows and between plants in a row. The distance may be reduced to 8 metres when the climate is comparatively dry and the soil is not so fertile.

Planting season

Planting of litchi should be done when the weather is neither too wet nor too dry. The best planting time is from August to September which, however, may be extended up to November in Punjab. Planting in spring and early summer may also be done if irrigation facility is available.

Planting

Before planting, pits of dimension 1 × 1 × 1m should be dug at the desired points a few weeks before the actual planting. These are then allowed to remain open for a few days and then filled with top soil mixed with manures and fertiliser at the rate of 20 to 25 kg farm yard manure, 2 kg of bone meal and 300 gm of muriate of potash. If available, a basket of soil from a litchi orchard which contains mycorrhizal fungi should also be added. The pits are then watered so that the soil settles down. At the planting time a small hole is made at the centre of the refilled pit and the desired clone is planted with the help of planting board. Water should be applied immediately after planting.

Care of young plants

Establishment of young plants in the field is one of the major problems in litchi cultivation. Because they are very exacting in their climatic requirements especially at the early stage, the plants will suffer if adequate attention is not paid. It is, therefore, essential that the young plants should be well protected against severe climatic conditions both in winter and in summer. For this purpose, a row of 'arhar' (*Cajanus cajan*) should be grown around the basin early in the spring and the quick growing plants will provide ideal protection to young litchi plants against the hot and desiccating winds in summer.

Besides, a few weeks after planting 50 gm of CAN (calcium ammonium nitrate) per plant should be added to the basins, leaving a width of about 15 cm around the stem. A light irrigation is given after mixing the fertiliser with the soil.

This dose of the fertiliser should be repeated every two months. This would help the young plants to make quick and vigorous growth.

Irrigation

For successful cultivation of litchi, adequate soil moisture is considered essential. Where annual rainfall is more than 125 cm and is well distributed throughout the year, litchi can be grown without irrigation. The young plants neither establish well nor do they make optimum growth if there is shortage of water. Adequate frequent watering is also essential for the bearing litchi trees. The development of litchi fruits takes place during March to May when the temperature starts rising in the plains of India and the atmospheric humidity remains very low. Evapo-transpiration consequently rises considerably. If the litchi orchard is not frequently irrigated during the spring and summer months, there is chance of severe fruit drop. The fruits which remain, do not develop fully, often split and become unfit for consumption.

Irrigation of young trees should be done by the basin system. As the trees grow, the basin should be gradually enlarged and thus in older plantation irrigation should be done by flooding or furrow method.

The orchard is irrigated after the application of fertiliser and when the fruits are set. At fruit set, irrigation is given at three weeks' interval which is reduced as the atmospheric temperature increases. Depending upon the availability of water, the orchard may be irrigated at fortnightly interval during April and frequency of irrigation may be increased further in May till the fruit is harvested.

Manuring and fertilisation

Though experimental data on the effect of manuring are not adequate, it is, however, certain that in litchi the nutrient requirements are very high. In particular, it requires high doses of organic matter. This helps greatly in increasing the water holding capacity of the soil, which in case of litchi, is of special significance. So in China, 227 kg of night soil per tree is applied every year (Groff, 1921). In order to overcome the tendency of the young plant to grow slowly, Marloth (1947) recommended that farm yard manure should be applied at the rate of 25 kg per young tree and up to 250 kg per tree of 20 years or more. Besides, the fallen leaves of litchi trees should not be removed as they form good mulch in addition to supplying organic matter to the soil. Some growers have also obtained good results with the addition of oil cakes to the litchi plants. Singh (1952) analysed the fruit of one variety and found that it contained high potash and suggested that this might be important nutrient for litchi. From the results of an investigation on the effect of different levels of calcium, nitrogen, phosphorus and potassium on growth and yield of litchi, Roy (1952) concluded that nitrogen markedly promotes growth, the variation due to the levels of the nutrient was not

significant. Calcium was also found to improve the health of the trees and where there were symptoms of potassium deficiency, the trees revived after the application of deficient element.

Nitrogen is the major nutrient and occupies an important position in the fertility programme for litchi. When nitrogen is deficient, the trees are stunted, the shoots make limited growth and bear leaves which are small and pale green. The leaflets are rough in texture with curling margins. The yellowing appears first in the old leaves and when the deficiency is severe the young leaves also become yellow. Young (1957) reported that sources and levels of nitrogen had very little effect on growth of the plants but in severe frost affecting areas, trees receiving sulphate of ammonia showed greater cold tolerance than those receiving nitrates. Yamadagani *et al*, (1980) in an experiment with 12 year old litchi plants var. Seedless recorded marked improvement in fruit set, fruit retention, length, diameter and weight of fruits by increasing the levels of nitrogen from 0·25 to 1·0 kg nitrogen per tree per year.

The amount of phosphorus used up by the plants is much less than nitrogen and potassium. The litchi trees grown under phosphorus deficient conditions remain stunted. The leaflets become abnormally large and dark green. The texture of the leaves is rough but not as rough as in the case of nitrogen deficient leaves. There are dark brown scorched areas in the old leaves, but in acute deficiency the leaves showed marginal necrosis of copper-brown colour Goldwebber (1959).

Potassium deficiency in litchi causes considerable stunting of the plants. The leaves are small and soft in texture. There is scorching of the leaf margin, starting from the tip and progressing gradually towards the base of the leaflet. In case of acute potassium deficiency, the leaves showed marginal necrosis (Anon. 1967).

Maximum growth and yield of litchi was recorded when the leaf N, P and K levels were 1·48 to 1·52, 0·15 to 0·18 and 0·90 to 1·05 per cent respectively (Koen *et al*, 1981).

Considering the above factors, the following fertiliser schedule (Table 1) was recommended for litchi (Nijjar, 1972) :

TABLE 1. MANURE AND FERTILISER SCHEDULE FOR LITCHI

Age of the plant	Per plant per year in kg			
	FYM	CAN	Superphosphate	Muriate of potash
1–3 years	10 20	0·3-1·00	0·2–0·6	0·05–0·15
4-6 years	25–40	1·0–2·00	0·75-1·25	0·20-0·30
7–10 years	40-50	2·0–3·00	1·50–2·00	0·30–0·50
10 years and above	60	3·5	2·25	0·60

Time and method of application

The farm yard manure, superphosphate and muriate of potash should be applied in autumn. Nitrogenous fertilisers should be divided into two equal parts and applied once in mid-February and again after the harvest of the fruit. In case of young plants, the farm yard manure and fertilisers are applied to the basins of the trees. The soil is hoed very lightly just to mix the manures with it. When the trees have grown large and the basins have been removed, the manure and fertilisers are broadcast over the entire field. After mixing the fertiliser with the soil, a light irrigation is suggested.

Effect of Zinc

As in many fruit plants, zinc deficiency is also recorded in litchi. Such a deficiency may be recognised from a general bronzing of the litchi leaves. The leaflets also become small and pointed and internodes remain short. The zinc deficiency in litchi may be corrected by spraying 4 kg of zinc sulphate and 2 kg of hydrated lime in 500 litres of water. The trees should be sprayed in spring as soon as they put out new leaves.

Training and pruning

After planting, a certain amount of pruning is often necessary to give proper shape to the litchi plant. Once the desired shape is achieved, no pruning is usually necessary, except the removal of dead or diseased branches and damaged shoots or crossed limbs. The pruning of bearing trees also includes removal of dead and diseased branches. Litchi flowers are borne mostly on current year's growth, and old shoot rarely produces flowers. Snipping of old branches to promote new growth is, therefore, desirable. This is, however, done indirectly when a part of the shoot bearing the cluster of fruit is removed during harvesting. If any litchi tree makes too much vegetative growth, both root and shoot pruning may be recommended. But it should be remembered that heavy pruning causes profuse vegetative growth which takes place at the expense of flowering and fruiting. When the trees become too old and produce fruits of small size, heavy pruning is advocated though it has got very little commercial importance as the yield is reduced and it is also not effective for more than a few years.

Intercropping

The litchi is a slow growing tree and takes at least six years to come to flowering and fruiting, so the vacant space in between the trees in the litchi orchard may be utilised effectively by growing intercrops during the early years. This will not only give a good annual income to the grower during the period till the litchi trees start bearing but will also protect the young litchi plant, enrich the soil, improve its physical condition and keep the weeds under control.

The choice of intercrops depends upon the climate and soil and also on the marketing facilities. At places near big cities vegetables may be grown with advantage, while cereals and leguminous crops like pulses may be grown at places away from the market.

The intercrops which may be grown profitably are as follows :

Summer and kharif season : During summer and kharif season, vegetables like pumpkin, cucumber, ridge gourd, bitter gourd and leguminous crops such as moong, kalai, cowpea, etc., may be grown. Sunnhemp or dhaincha may also be grown as a green manure crop which will protect the young litchi plants against hot desiccating winds and at the same time will enrich the soil.

Winter season : In this season radish, beet, turnip, cauliflower and carrot may be grown in the young litchi orchards. Peas, beans and gram also make excellent intercrops.

Besides vegetables and pulses, some quick growing fruit plants such as phalsa, papaya, pineapple and banana can also be grown in the early years of a litchi plantation. Papaya and banana, because of their upright growth, lend themselves extremely well as an interplant in the litchi orchards. The most productive period of these fruit plants would be over by the time the litchi trees come into bearing and they can then be removed from the orchard. These two fruit plants being very fast in growth, provide good protection to litchi plants during the early years.

But care should be taken to ensure that these intercrops are not grown at the cost of the litchi plants. These should be manured separately and protected from the attack of pests and diseases.

Mulching

As soil moisture is one of the important limiting factors for successful cultivation of litchi, use of mulch is very beneficial. It reduces the loss of moisture from the soil, enhance the rate of penetration of rain water or irrigation into the soil and controls the growth of weed, thus eliminating the competition between the weeds and the fruit trees. The use of mulch will encourage the development of better root-system of young litchi plants at a much faster rate than in the case of the plants growing in a bare soil.

The farm yard manure, compost or straw may be used as soil mulch, the first two are excellent because they enrich the soil in addition to conserving soil moisture. When straw is used as a soil mulch, an additional dose of 25 to 35 kg of calcium ammonium nitrate per tonne of dry straw should be applied to hasten the rotting of this material. Otherwise, the litchi plants will suffer from nitrogen starvation. Besides, cutting down of tall weeds growing in the orchard and leaving them spread over the orchard soil also provide a good mulch.

13.8 Flowering, Floral Biology, Pollination and Fruit Set

Flowering

Litchi trees from airlayer may come to flower at the age of 3–5 years with proper care and management. In South India, flowering starts at about 6 years after planting. Seedlings take 8 to 12 years to flower. In almost all the litchi growing states of India, flowering starts from the latter part of January or early February and fruits begin to ripen in May and June. In South India, flowering starts in December and fruits ripen in April to May. In litchi, the inflorescence is a much branched panicle normally developing from the terminal buds of the previous season's growth. Panicles may be pure as well as mixed. Litchi varieties show variation in their flowering and bearing habits and may accordingly be classified as regular, irregular, shy bearing, etc. Even a variety may differ in its flowering intensity from one year to another due to varied environmental factors as well as bearing performance of the previous year. If new flushes appear in autumn due to late rain, the new shoots usually fail to bear flowers in the next spring. So in places like Hawaii where this is very common, the litchi trees are sprayed with NAA in autumn to promote flowering (Shigeura, 1948; Bonner and Liverman, 1953). It was suggested that the treatment caused faster maturation of the shoots. Girdling round the branch or trunk also increased flowering and fruiting in some varieties of litchi and flowering and fruiting were heavy after September or October girdling as compared to non-girdled or November girdled trees (Nakata, 1953 and Young, 1957). Girdling was, however, ineffective if the tree was in poor health or had not produced a flush of growth six months before flower bud initiation. In dry areas, it should be done in alternate years or only half the tree should be girdled in one year. Before girdling, the trees should be given a dose of complete fertiliser in July, after harvesting of fruits in order to induce vegetative flush.

In litchi, it has been reported that between photoperiod and temperature, the latter has a direct influence on floral initiation. None of the litchi plants exposed to short (8 hours light) day and long (16 hours light) day flowered under a night temperature of 75°F (23·9°C) and flowering occurred only when the night temperature was maintained at 60°F (15·5°C) or lower for a period of about two months. Flowers were initiated in the plants kept in the green house (16 hours light) and outdoors (12·1–12·8 hours day) after the minimum temperature dropped to and below 65°F (18·3°C) for a period of 30 days (Nakata and Watanabe, 1966).

In litchi, numerous small flowers without petals are borne on terminal panicles, mainly on new shoots. The flowers are mainly staminate, hermaphrodite and pseudohermaphrodite. The first flowers to open are males, followed by hermaphrodites functioning as females and pseudohermaphrodites functioning as male (Singh and Singh, 1954). So for effective pollination and fruit set of

litchi mixed planting, i.e., growing of several varieties together in an orchard is recommended.

Floral biology

Studies made on floral biology, fruit set and its retention in five varieties of litchi, viz., Dehra Dun, Muzaffarpur, Calcutta Late, Seedless No. 1 and Seedless No. 2 under Gurudaspur condition, Punjab, showed that emergence of panicles commenced in the first week of January and continued up to the third week of February. Opening of flower started in the second or third week of March. Flowering period ranged from 26 to 35 days in different varieties. Anthesis and dehiscence in all varieties continued throughout the day and night. Maximum dehiscence took place at 10 a.m. No correlation between temperature, humidity and anthesis and dehiscence could be established. Seedless No. 1 produced the highest number of flowers per panicle, while Muzaffarpur the lowest. Calcutta Late produced the highest percentage of hermaphrodite flowers, and the maximum fruit set, while in Dehra Dun the less number of female flowers resulted in the lowest fruit set and thereby exhibited a distinct correlation between sex ratio and fruit set in litchi (Kanwar and Nijjar, 1975).

Pollination and fruit set

In litchi, pollination is mainly done by insects such as honey bees, flies, ants and wasps. Presumably, the 'seedless' fruits in which the seed is shrivelled, develop without fertilisation and such varieties are likely to be self-sterile and perhaps cross-sterile also, while those with normal seeds are probably self and cross-fertile. It is thought that pollination is necessary even for the seedless type, this being a case of stimulative parthenocarpy. Though the litchi trees flower profusely, only a small percentage of the flowers develop into fruits ; 20 fruits on a panicle finally produce a good crop. Failure in setting and the drop of many of the fruits during the first month may be due to lack of fertilisation or embryo abortion.

13.9 Fruit Growth and Development

Fruit growth

In fruit growth of litchi, seeds develop initially at a high rate, followed by membranous mesocarp and aril which grow very fast towards the later stage of fruit development. Kanwar *et al*, (1972) observed that the period of active seed growth, i.e., from fertilisation up to the second week of May was marked by a complete lack of flesh growth and whatever increase in fruit diameter was recorded it was mainly due to the increase in seed diameter. They also reported that under Punjab conditions in vars. Calcutta Late and Seedless No. 1 flesh growth commenced from May, 14 and it increased rapidly up to the harvesting date

and the period between the second week of May and first week of June was critical for fruit cracking. Kanwar and Nijjar (1976) in another experiment concluded that the first phase of fruit growth was manifested by seed development and in the second phase flesh growth occurred. In West Bengal, the flesh growth was found to occur from the second week of April and the maximum increase was observed between fourth week of April and first week of May in vars. Bombai, Elachi, Mazzafarpur, China and Bedana. The total soluble solid and total sugar contents of fruits were found to increase steadily from the second week of April and continued till the last week of May (Ghosh, unpublished).

Fruit drop

Maximum fruit drop occurred during second and third week after fruit set (Mustard *et al*, 1953 ; Lin, 1955 ; Mallik 1961 and Hoda *et al*, 1973). The variety Calcutta Late bears the highest number of fruits to maturity, while Dehra Dun the least (Chadha and Rajput, 1969). Calcutta Late and Seedless Late are less prone to fruit drop than Dehra Dun, Muzaffarpur and Seedless Early. Apart from the competition among fruits for water and nutrients and other physiological causes, strong wind significantly affects drop. Irrigation to bearing litchi trees twice a week from April onwards and good wind break minimise fruit drop to a great extent (Kanwar and Nijjar, 1975).

Foliar spray with $ZnSO_4$ at 0·5, 1 and 1·5 per cent on Dehra Dun variety considerably increased the Zn content of the leaves and effectively reduced fruit drop, increased fruit, pulp weight and TSS and decreased total acidity. Higher level of Zn in the leaves might increase the endogenous production of auxins and thereby reduce the fruit drop (Awasthi *et al*, 1975).

Treatment with $ZnSO_4$ mixed with hydrated lime in 2 : 1 ratio as foliar spray at concentrations 0, 0·5 and 1 per cent on new growth flush of 32 year old Purbi litchi trees on 13th February, followed by application of NAA and 2, 4-D at concentrations 5, 10 and 20 ppm each on 30th March after the total fruit set and repeated thrice at weekly intervals indicated that 1 per cent $ZnSO_4$ spray caused marked reduction of fruit drop. Further, growth substances proved more effective with Zn. Both NAA at 10 ppm and 2, 4-D at 15 ppm in combination with 1 per cent $ZnSO_4$ resulted in more fruit retention till harvest ; 2, 4-D at 20 ppm caused injury to the fruits (Hoda *et al*, 1973). Mallik (1961) also found NAA 10 ppm to be effective in reducing fruit drop in litchi. The aril and juice contents in fruits also increased by Zn and growth substance sprays. Zn had little effect in increasing the sugar content whereas growth substance had a marked effect and NAA 10 ppm was superior to other treatments. Both Zn and growth substances increased the acidity and it was maximum at 1 per cent Zn (Hoda *et al*, 1975).

13.10 Pests and Diseases and Physiological Disorders

Serious insect pests and diseases seem to be relatively few in litchi.

Pests

Mites : In India maximum damage to the litchi is done by the eriophid mite (*Aceria litchi*). Both adults and nymphs infest the leaves. The adult mites are small (1/15 mm long) whitish insects hardly visible with naked eyes. They live at the base of hairs on the under surface of the leaves and cause a brown velvety growth. Pits are formed which develop into galls and finally the leaves curl up. The mites suck sap from the leaves causing them to dry up. Vigorously growing young trees and new growth of adult trees are most likely to be attacked and seriously damaged. The attack of mites starts in March and the maximum activity is in July. The life-cycle of the pest is completed in about a fortnight. The adults pass the winter on the leaves.

Spraying with Kelthane 0·12 per cent during the new flush period at three week interval would be highly effective (Mathur and Tandon, 1974). Alternatively, Dimathoate 0·05 per cent can be used in case Kelthane is not available.

Caterpillar : The next improtant insect pest of litchi in India is bark eating caterpillar (*Indarbela tetraonis*). The adult moth of this pest lays eggs during May and June in groups of 15-25 which hatch after 8-11 days. The larvae web shelters of wood, silk and excreta and feed on the suface of the bark till September. Afterwards they bore into bark and underlying tissues in the branches. These become full grown in December and pupate in late April. Plugging the holes with fumigants such as carbon bisulphide, petroleum or formalin and then plastering with mud checks the caterpillars effectively.

Besides, in certain litchi growing areas of India, a small caterpillar is found to eat the stalk end of the fruit and seed without affecting the pulp. It produces a brown dust like substance and causes considerable damage to ripe fruits and reduces the market value of the fruits. Spraying with Demicron (0·6 ml/l), Rogor (3 ml/l) or Thioden (3 ml/l) about 15 days before the fruits mature reduces the infestation.

The bats and birds also cause considerable loss of fruits. They can be scared effectively by beating drums or by firing crackers.

Disease

Litchi is almost free from fungus diseases in India.

Physiological disorders

Fruit cracking is a serious problem in almost all the litchi growing areas of India, particularly under dry conditions. It is thought to be due to high temperature and relatively low humidity and these factors in combination with rapid flesh

growth and relatively less elasticity of fruit skin cause cracking. As a result of this a sizable amount of fruits becomes unfit for marketing. This can be overcome by providing ample irrigation during the development to fruits. Mulches may also be tried to check this malady. Besides, treatment with 2, 4, 5-T or NAA at 35 to 100 ppm has been found effective in controlling the splitting of fruits and also to increase their size.

13.11 Harvesting

Harvesting is usually done in May and June when the fruits mature properly. The maturity of the fruit is determined by the flatness of tubercles and comparative smoothness of the epicarp. Besides, the fruit colour changes from greenish to pinkish on maturity. The fruits are harvested in bunches along with a portion of the branch and few leaves. This helps in improving the keeping quality of the fruit and at the same time the tree receives mild pruning. As all the fruits on a tree do not ripe at the same time, the fruit clusters are spot-picked several times. If individual fruit is harvested, the skin at the stem end is ruptured and fruits rot quickly. The fruits should not be harvested immediately after rains when the trees are wet, as the spoilage of the fruit in storage would be high.

13.12 Yield

After the litchi trees come into bearing, the yield increases till they are 20 to 30 years old. With proper care and management and under suitable environmental conditions, a litchi tree may continue bearing economic crop for over 100 years of age. In Queensland, litchi trees bear crop only once in two or three years and the average yield is about 200–300 lbs (90·8–136·2 kg) per tree (Stephens, 1935). In Hawaii, there is an occasional yield as high as 1000 lb (454 kg) per tree (Popenoe, 1920). Groff (1921) stated an yield up to 1500 lb (681 kg) in China. Viyas (1938) reported an average yield of 4000 to 5000 fruits weighing between 164 and 328 lb (74·4 148·9 kg) per tree in Uttar Pradesh. In India, a full grown litchi tree on an average bears about 80 to 150 kg of fruit per year (Nijjar, 1972).

13.13 Storage and Ripening

Storage

The fruit does not keep for more than a few days at room temperature. It looses its bright red colour and turns brown within 2-3 days after harvest. In a trial with litchi, Chaudhuri and Banerjee (1959) reported that at 36 to 38 °F (2.2 to

3·3 °C) and relative humidity of 80 to 85 per cent, fruits could be stored in a normal condition for one month. Campbell (1959) also studied the storage behaviour of Bengal litchi and reported that fruits could be stored for 5 weeks at 35 and 45 °F (1·6 to 7·2 °C) in perforated polythene bags without much wastage and physiological characters of the fruits were better than those at 60° and 70 °F (15·5 to 21·1 °C). Moreuil (1973) noted that freshly harvested fruits when rapidly cooled and kept at − 25 °C remained in excellent condition for 12 months. Lin (1982) in Taiwan, observed that unwrapped litchi turned brown within 4 days at 20 °C, while it took 8 days when stored at 5 °C or 0 °C. Gaur and Bajpai (1979) observed that at room temperature, fruits treated with $CuSO_4$ or sodiun hypochlorite and placed in perforated polythene bags showed little spoilage after 7 days. Fruits of var. Bombai could be stored for 12 days at 2·5 °C or by treatment with Celmone (a NAA preparation) at 40 ppm (Ghosh, 1980).

Another method of preserving litchi fruits is drying, either in the sun or in an oven. Sun dried litchi is considered better than artificially oven dried fruit. As the dried flesh and the seed rattle inside the hard shell, the product is called the 'litchi nut'. Litchi fruits can also be frozen with minimum handling, the natural covering of the fruit is a good packing material by itself, and the whole frozen fruit makes an attractive product. It can also be peeled and frozen in syrup as is done with other fruits (Linder *et al*, 1946). Recently, canning of litchi in large quantities has also been taken up in India. The canned product is of excellent quality and has demand in the market.

Ripening

Litchi ripens when the atmospheric temperature is high. Unlike mango, litchi fruits usually do not improve in quality after harvest. So the fruits should be allowed to ripen properly on the tree. The development of red pigmentation of litchi fruits was found to be associated with four anthocyanin pigments (Prasad and Jha, 1978). Spraying of the litchi fruits with Ethrel at 250 ppm was found to increase the anthocyanin content (Ghosh, 1980).

Bhattacharyya and Mohan (1977) reported that dipping the fruits of var. Khatti in Ethrel at 250 ppm solution improved the fruit colour and the peeling of fruit also became easier. Treatment with Ethrel not only increased the total sugar content of fruit but also accelerated the ripening time by about 2 to 3 days.

13.14 Marketing

The fruits for the local market should be collected at the full ripe stage as indicated by the attractive skin colour, while for distant market, the fruits should be harvested when they have just started to turn reddish. After harvesting, the fruits should be kept in cool, dry and well ventilated rooms because the litchi fruits

ripen under high atmospheric temperature. If the fruits are exposed to sun even for a few hours after harvest, their quality deteriorates markedly. The fruits are graded and packed in shallow baskets or crates lined with litchi leaves or soft dry grass or banana leaves. Thinner boxes are preferred. The fruits should be packed loosely in the container and free circulation of air through the package should be ensured. During transit, care should be taken to avoid crushing of fruit and damage of the skin. Litchi being a highly perishable fruit, its marketing should be done as early as possible. Since its production is relatively low in India, disposal of the fruit is not a problem at present.

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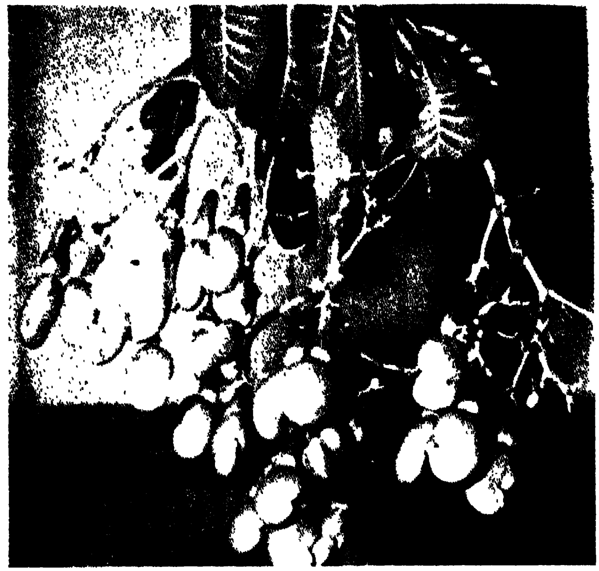
A cashew tree

A cashew panicle
with immature nuts



Stages of development of nut and apple

14

CASHEW

M. C. NAMBIAR and P. K. THANKAMMA PILLAI

Cashew (*Anacardium occidentale* L.) is one of the most versatile tree crops which ranks third in the international trade of tree nuts with 20 per cent of market, after hazel nuts (29%) and almonds (21%). The Portuguese, who were aware of the use of cashew in medicine, foods and beverages, introduced it into Malabar Coast of India in the 16th century. Cashew was reported to have been originally planted mainly for checking soil erosion. It was only in the beginning of the 20th century that the cashew kernel gained importance and the crop began to be considered as a horticultural crop of commercial importance.

14.1 Composition and Uses

Every part of cashew is useful to man. The kernels are of high nutritive value. It is rich in protein, carbohydrate, unsaturated fats, minerals like calcium phosphorous and iron, and vitamins (Table 1).

TABLE 1. COMPOSITION OF CASHEW KERNEL AND APPLE

Kernel		Apple	
Constituents	Percentage	Constituents	Percentage
Moisture	5·9	Moisture	87·9
Protein	21·0	Protein	0·2
Fat	47·0	Fat	0·1
Carbohydrate	22·0	Carbohydrate	11·6
Mineral matter	2·4	Mineral matter	0·2
Phosphorus	0·45	Calcium	0·01
Calcium	0·55	Phosphorus	0·01
Iron	5·0 mg/100 gm	Iron	0·2 mg/100 gm
Carotene	100 I.U./100 gm	Vitamin C	261·5 mg/100 gm
Vitamin B_1	630 mg/100 gm		
Riboflavin	190 mg/100 gm		

Cashew proteins are complete with all essential amino acids. Hence it can be considered equal to peanut and soybean for proteins and to meat, milk or egg for protein substances. The kernels supply about 6000 calories energy per kg as against 3600 by cereals, 1800 by meat and 650 by fresh fruit. As the nut fats are complete, very active, easily digestible and non-fattening, it can be used by both old and infants alike.

The cashew apple juice is rich in vitamin C (261·5 mg/100 gm) content, up to five times that of citrus fruit. It contains 10·15 to 12·5 per cent sugars (mostly reducing) and about 0·35 per cent acid (as malic).

The mesocarp of the shell consists of honeycomb like cells containing a viscous liquid called the cashew nut shell liquid (CNSL) which provides a natural protection to the kernel against insects. CNSL is a valuable raw material for a number of polymer-based industries like paints and varnishes, resins, industrial and decorative laminates, brake linings and rubber compounding resins (Kamath, 1956).

In addition to the popular use of cashew trees for firewood, charcoal, etc., the pulp from the wood is used to fabricate corrugated and hard bound boxes. There are many medicinal uses for cashew apple and its juice. It is a good remedy for scurvy, cough and colds, and is an excellent purgative. The cardanol and anacardic acid of the shell possess powerful rubefacient and vesicant properties and the oil obtained from the shell is used to cure cracks on the sole of feet.

14.2 Origin and Distribution

Cashew tree is believed to be a native of Brazil, from where it was dispersed to many of the tropical areas. It was introduced to the Malabar Coast of India in the 16th century by the Portuguese and the Malabar Coast probably served as a locus of dispersal to other centres in India and South-East Asia (de Costa, 1578). Also from India it was carried eastward to Amboina in Indonesia (Rumphius, 1962) ; dispersal of the species to South-East Asia appears to have been carried out by birds, bats, monkeys and human agents (Burkill, 1935 ; Johnson, 1973).

The earliest record of the cashew trees in South-East Asia is that of de Loureiro (1790). But according to Johnson (1973), it was introduced to that region by the Portuguese much earlier. Most of the names for cashew in Indian languages are derived from the Portuguese name *Caju* which in turn originated from *Acaju*, the name given to cashew by the Tapi Indians of Brazil. At present, the major cashew producing countries are Mozambique, Tanzania, India, Brazil, Kenya and Madagascar. As many as 20 species of *Anacardium* are known to exist within Central and South America. However, *A. occidentale* is the only species reported to have been introduced outside the New World.

14.3 Species and Varieties

The family Anacardiaceae to which cashew belongs comprises 60 genera and 400 species of tropical and subtropical trees and shrubs. In India, about 50 species under 22 genera are recognised. But according to Bailey (1958), *Anacardium* is a small genus with 8 species whereas Agnoloni and Giuliani (1977) recognised eleven species. However, as many as 20 species of *Anacardium* are known to exist in Central and South America (Table 2). A number of these species are probably synonymous.

TABLE 2. SPECIES OF GENUS *ANACARDIUM* LINN

Botanical Name	Country
Anacardium brasiliense Barb.	Brazil
A. curatellaefolium St. Hil	Brazil
A. encardium Noronha	Malaya
A. giganteum Hancock ex Engl.	Brazil
A. humile St. Hil	Brazil
A. mediterraneum Vell.	Brazil
A. nanum St. Hil	Brazil
A. occidentale Linn. (Cashew nut)	Brazil
A. rhinocarpus D.C.	Columbia, Venezuela
A. spruceanum Benth Ex. Engl.	Brazil
A microsepalum Loes	Amazon Region
A. corymbosum Barb.	Brazil
A. excelsum Skeels	Central America
A. parvifolium Ducke	Amazon Region
A. amilcarianum Machado	Brazil
A. kuhlmannianum Machado	Brazil
A. negrense Pires and Froes	Brazil
A. rondonianum Machado	Brazil
A. tenuifolium Ducke	Brazil
A. microcarpum Ducke	Amazon Region

Valeriano (1972) considered that the division into *A. nanum* (dwarf) and *A. giganteum* (giant) be the only sure, rational and practical way and each species divided into varieties characterised by colour (yellow or red) and shape (round, pear-shaped or elongated) of apple. He also described various subvarieties, among which included Maca (apple) and Manteiga (butter) well-known in Brazil.

	Very good Class I	Good Class II
1. *Soil characteristics*		
1.1. Depth of soil	1·5 m	90 cm- 1 m
1.2. Texture	Loam Sandy loam	Loamy sand Silty loam Coastal sand
1.3. Reaction	Slightly acidic to neutral (pH 6·3-7·3)	Slightly acidic (pH 6·0–6·3)
2. *Land features*		
2.1. Slope (%)	<3	3-5
2.2. Watertable (m)	2 5	1·5-2·0
2.3. Erosion condition	None to slight (e_0)	(Coastal belt) Slight (e_1) sheet erosion
2.4. Drainage	Well-drained	Well-drained to somewhat excessively drained
2.5. Physiography	Coastal plain Delta reaches Shield plains Inland laterite regions adjoining coastal plain	Alluvial plain Natural lavees Upland plains Coastal ridges
3. *Climate and environmental factors*		
3.1. Altitude (m)	>20	20–120
3.2. Rainfall (cm/year)	150–250	130–150
3.3. Proximity to sea (miles)	50	50–100
3.4. Temperature		
3.4.1. Maximum in summer (°C)	32·2–37·7	37·7–39·3
3.4.2. Minimum in winter (°C)	15·5	13–15·5
3.5. Humidity (%)	70–80	65–70
3.6. Occurrence of frost	None (once in 20 years)	None (once in 15 years)

LAND FOR CASHEW (Mahapatra and Bhujan, 1974).

Fair Class III	Poor Class IV	Unsuitable Class V
45 cm-90 cm	23 cm–45 cm	< 23 cm
Clay loam Silty clay loam Sandy clay loam Loamy skeletal	Gravelly clay loam Gravelly silty loam Gravelly sandy loam	Gravelly clay Sandy clay Silty clay Clay
Medium acidic (pH 5·6–5·9)	Strongly acidic (pH 5·1–5·5) or mildly alkaline (pH 7·4–7·8)	Very strongly acidic (pH less than 5·0) or alkaline (pH more than 7·8)
5–15	15 25	> 25
8–10	10–13	> 13
Moderate (e_2) (Rill and sheet erosion)	Severe (e_3) (Gully erosion)	Very severe (e_4) Gully and ravine erosion
Moderately well-drained	Excessively drained and imperfectly drained	Poorly drained
Plateaus	Denuded hill slopes with shallow soils	Swamps
Hills, domes, mounds	Ridges, steeply undulating terrain with severe erosion	Valley, bottoms Escarpments Steeply slopping mountain creek plain
120–450	450-750	> 750
110–130	90–110	> 250
110–150	150 200	> 200
39·4–41·1	41·1-43·3	> 43·3
11·6–13·3	8·8–11·1	< 8·8
60–65	50–60	< 50 or > 80
Very rare (once in 10 years)	Occasional (once in 5 years)	Very often to frequent (every year)

De Candolle (1825) sub-divided *A. occidentale* into two varieties—Americanum and Indicum—on the basis of the ratio of nut to peduncle. Two varieties based on apple colour – red and yellow—have been identified in many cashew growing countries (Morada, 1941 ; Cordoba, 1967 and Araque, 1968). Aiyadurai (1966) reported the existence of cashew apples in India having varying intensities of yellow, red and pink colour. Mukherjee (1956) recognised six types in West Bengal based on apple and nut characteristics, while Sebastine (1955) reported only four types from Travancore-Cochin.

From the state of Ceara in Brazil, Peixoto (1960) and Martins (1965) described a variety with small nut, thin skin and no shell, which can be eaten raw.

Among the several species in the genus *Anacardium*, *A. occidentale* L. (cashew nut) is the most important and a number of promising accessions are recognised under this species.

14.4 Soil and Climate

Soil

Cashew can be cultivated in a wide variety of soils. In India, even now, cashew is a crop of the marginal lands. It can survive even in wastelands of low fertility and can be grown in almost all soil types from sandy sea coast to laterite hill slopes, but the best soils are deep, friable, well-drained sandy loams without a hard pan. It cannot withstand water stagnation, flooding or bad drainage.

In India, cashew is mainly grown in laterite, red and coastal sands in Kerala, Maharashtra, Goa, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. Mahapatra and Bhujan (1974) have prepared a very useful 'rating chart' for land selection for cashew in Orissa (Table 3).

Climate

Cashew is mainly a crop of the tropics. Its distribution extends up to latitudes 27° N (South Florida) and 28° S (South America) (Joubert and Thomas, 1965). It can tolerate a wide range of soil and climatic conditions and the major limiting factor is its inability to tolerate frost and extreme cold for a long time. Its distribution is restricted to altitudes below 700 m where temperature does not fall below 20°C for prolonged periods. It requires a minimum rainfall of 50 cm per annum, but can withstand from 30 to 400 cm. If there is sufficient water supply, it can withstand long periods of low relative humidity also. Cashew is a sun-loving tree and does not tolerate excessive shade. Very high temperatures (39–42 °C), however, during the marble stage of fruit development cause fruit drop. Heavy rains and cloudy weather adversely affect the yield in cashew.

14.5 Area and Production

The area under cashew in India was 4,51,900 ha and the production 1,37,200 tonnes in 1979-80 which comes to about 27 per cent of the total world production. The statewise area and production of cashew nut in India are given in Table 4.

TABLE 4. STATEWISE AREA AND PRODUCTION CASHEW NUT IN INDIA (1979-80).

State	Area (000 ha)	Production (000 tonnes)
Andhra Pradesh	38·2	7·6
Goa, Daman, Diu	41·6	6·1
Karnataka	53·2	15·2
Kerala	147·3	83·9
Maharashtra	30·0	4·3
Orissa	38·8	7·0
Tamil Nadu	94·8	10·4
West Bengal	6·7	2·4
Others	1·3	0·3
INDIA	451·9	137·2

Source : Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India.

14.6 Propagation

Seed

In India, most of the existing plantations as well as the small holdings were raised from seeds. Normally, fully matured seeds of the current season are preferred for sowing.

The seeds should be collected from selected mother trees possessing certain parameters like compact canopy, more intensive branching, a high percentage of flower bearing laterals, a larger proportion of bisexual flowers and fruit set of more than five nuts per panicle. Madhava Rao (1974) reported that a combination of kernel size and gross yield are the major criteria for selection apart from the size of nuts, shelling percentage, shorter flowering phase and minimum difference between length of style and stamen. The nuts selected for raising seedlings should be of medium size, good shape and high specific gravity (Turner, 1956 ; Auckland, 1961 ; Northwood 1967). Menon *et al.* (1979) observed early emergence of cashew seedling with higher percentage of germination by using seeds having higher specific gravity.

The best period for collecting seed nuts is March-April to be sown in June with the onset of monsoon, either directly in the field or in polythene bags. The

seedlings raised in polythene bags can be transplanted in the field when they are 6 to 8 weeks old.

Vegetative propagation

Cashew can be propagated either from seedlings or clonal material and vegetative propagation provides the most reliable progeny because cashew is highly cross-pollinated. Vegetative propagation has got many advantages over seedling propagation. In the first place, true-to-type can be raised by vegetative methods. Gowda *et al*, (1976) reported that all the vegetatively propagated trees were precocious and yielded better than trees raised from seeds. Damodaran *et al*, (1979) also reported that the air-layers and grafts yielded three times more than that of seedling progenies.

In cashew, various methods of clonal propagation have been practised with considerable success. Seasonal factors and management practices play an important role in the success of multiplication. Layering, budding and grafting are the important methods of vegetative propagation in cashew.

Layering

Layering is one of the earliest methods attempted in India and Tanzania. The two methods of layering adopted in cashew are (i) air-layering and (ii) mound-layering.

Air-layering : At present, air-layering is one of the common methods of vegetative propagation in cashew. For this, shoots of pencil thickness of previous year's growth (preferably not bearing flowers) are used. A ring of bark of about 3 cm long is removed and a lump of saw dust, previously soaked in water is placed in a polythene film of 25 × 20 cm and is wrapped closely around the cinctured portion. The ends of the film are carefully tied and left for rooting. It takes about 60-80 days for rooting and the time of separation of the layer can be fixed by observing the root system through the polythene film. The layers are separated from the mother tree by giving a notch at the first instance and deepening the cut after a gap of 10 days and final separation after another 7 days. Though it is preferable, it is time consuming. Hence it is better to separate the layer completely by single cut after root formation. The layers after separation are planted in suitable containers and kept under shade before transplanting. Chhonkar and Singh (1967) reported 88 per cent rooting in air layers by applying 75 ppm IBA in lanolin as compared to 71 per cent under control. While Melanta (1983) obtained higher percentage of rooting by treatment with 500 ppm IBA.

Mound-layering : The technique of mound-layering consists of cutting down the selected tree to the ground level and treating the cut end with fungicides to prevent fungal infection. Within two to three months many buds start sprouting from the ground level. These are covered with sand and soil up to 15-20 cm

and after 30-40 days, the shoots which turn from green to brown are cinctured and treated with root-inducing hormone like IBA and again covered with sand. The cinctured shoots produce roots in 30-40 days. The sand mound around the stump is removed and the shoots are separated for planting. The number of layers that can be obtained by mound-layering is low.

Budding

The technique involved in budding is of selecting a mature shoot from previous year's growth and forcing it by clipping the lamina into halves and leaving them as it is for about a week to activate the axillary buds. The cashew seedling used as rootstock is prepared by removing side growth up to 20-25 cm from the base. The budding operation consists of removing a rectangular patch of bark with a bud from the budwood by giving two transverse and two vertical cuts. A corresponding patch of bark is removed from the stock plant. The bud is then placed on the stock and wrapped with a plastic film either fully covering the patch or in such a way that a small patch of bud is left uncovered (Ascenso and Milheiro, 1973). If the take is perfect, the bud starts sprouting within a month. Ferraz *et al*, (1974) observed 99·59 per cent take in patch budding, on eight month old seedling when carried out during the dry season. While 71 per cent success in the month of July and only 50 to 58 per cent success in March, April, September and October were noted by Palaniswamy and Hameed (1976).

In the Forkert budding, instead of removing a portion of the bark of stock plant, the bark is loosened by two vertical incisions, connecting the two with a transverse cut at the bottom. The bud is inserted into the flap by lifting the flap upwards and the bud, so covered with the flap, is wrapped with plastic film. The wrapper is removed after three weeks and if the bud is green, the flap is cut to expose the bud for further development.

Grafting

Compared to budding, grafting is laborious. Different grafting techniques like veneer, side, wedge, tip and cleft grafting, etc., have been tried in cashew with different degrees of success. A few important methods are described below :

Veneer grafting : For veneer grafting, vigorous seedling about six months old are ideal. Forcing of scion shoot for 7-10 days prior to grafting is necessary. Forced scions are detached and kept in moist saw dust to avoid desiccation. The scion is prepared by a long cut of about 3-4 cm along one side and a short one at the base from opposite side to get proper fitting on the stock matrix. A smaller cut is made about 10-15 cm above the base of the stock plant. The cuts on the scion as well as on the rootstock should be of same size. After placing in the correct position, it is properly tied with polythene film. The union takes place in 3-4 weeks and the stock can be cut back in a slanting position in steps.

Phadnis (1971) suggested to use seedlings below 5 months and not more than 50 cm in height with a girth of 4 cm for veneer grafting.

Side grafting : For this, 2-3 year-old seedlings raised *in situ* are used. Two vertical cuts are made (4-6 cm in length) on the stock plant corresponding to the thickness of the scion and detached from the trunk. Scion can be prepared by a long shallow cut on one side and another small slice on the opposite side to facilitate pushing the scion into the groove on the trunk portion of the stock. The cut end of the scion is carefully pushed into the groove and covered with the rind flap before wrapping with polythene strip. The terminal bud of the scion starts to grow within a month. The top of the stock plant is generally lopped in stages to push up the growth of the scion.

Whip grafting : In this, a cut of about 5-6 cm long on one side is made on the forced scion and a smaller on the apical protion of the stockseedling. The cut surfaces of the scion and stock are fixed properly and wrapped tightly with a polythene strip. The terminal bud of the scion sprouts within three weeks, if the take is perfect.

Cleft grafting : Forced scion of pencil thickness is used for cleft grafting. Two slanting cuts on either side of the scion are made to form a wedge. The seedlings to be grafted should be given a clean cut from the base horizontally at the centre to facilitate insertion of the wedge-shaped scion. The joint is tied with polythene film. Ascenso and Milheiro (1973) reported 100 per cent success in cleft grafting by using stock and scion, 3 5 mm in diameter.

Tip grafting : For this, 5-12 months old stock and scion from the current season's shoot are used. The tip of the shoot is whip grafted and tied, and the terminal bud is covered with a speparate polythene film.

Epicotyl grafting : In this, 4-8 day old seedlings are cleft grafted. The scions are prepared by prior defoliation of shoots of comparative thickness. The grafts are planted in pots immediately and watered. The scions start sprouting within one month. Epicotyl grafting in November gave 100 per cent stand in the field and the grafted plants started flowering within two years (Nagabhusanam, 1982).

Approach grafting or inarching : The rootstocks are raised in containers. The scions are selected and the stocks are brought near the selected scion shoots. A strip of bark, about 5-8 cm long with a part of wood, is removed from the stock as well as from the scion and attached properly and wrapped. After union the scion shoot is cut below the graft and the rootstock is cut above the graft.

Soft wood grafting : The soft wood grafting technique consists of raising a rootstock *in situ* for one year or more and grafting by wedge method on terminal new growth of stock. Scion wood to be used should be defoliated 10 days prior to grafting and should have the same thickness of the stock. The graft should be secured firmly using 1·5 cm wide and 45 cm long polythene strips.

Top working

Grown up trees can be converted into any desirable type by periodically dehorning the main limbs of the tree, allowing new soft shoots to produce and grafting these new shoots by soft wood grafting technique.

Cutting

Peixoto (1960) reported that propagation by cuttings is possible in cashew and best results are obtained with lateral shoots and water-shoots from latent buds. Even though propagation by cutting has certain advantages, a good methodology for this is not so far available.

14.7 Cultivation

Land preparation

Cashew is a very hardy crop. Hence soil depth, slope, soil fertility and availability of water, etc., are not limiting for the cultivation of cashew. But waterlogged soils and excessive salinity/alkalinity should be avoided. For raising a new plantation, land preparation should begin as soon as the pre-monsoon showers are received. The major operations are cleaning the land, digging of pits ($50 \times 50 \times 50$ cm) and terracing or bunding of slopy lands. Sowing of seeds or planting of seedlings and clonal progenies are usually done by the onset of South-West monsoon. A spacing of 7×7m to 8×8m is recommended for cashew.

Raising seedlings

For raising seedlings in the nursery, seed nuts are sown in polythene bags after soaking in water for 2-3 days. The nuts will germinate in 15-20 days. When sown directly in the field, two to three seeds are sown in each pit. Madhava Rao *et al*, (1957) reported that the seeds are best sown 2·5 cm deep in a slanting position.

In sandy soils, watering of seedlings during summer months is necessary.

Manuring and fertilisation

In India, manuring is seldom done regularly for cashew, though research work on cashew showed that it requires regular fertiliser application to ensure early and higher yield (Table 5).

Symptoms due to deficiencies of N, P, K, Ca, Mg, S, Mo, Cu, etc., in seedlings grown in pots receiving nutrient solution have been described by Ohler and Coestar (1979). Mahapatra *et al*, (1973) recorded that the annual nutrient removal in a 30-year-old cashew tree was 2·80 kg N, 0·75 kg P_2O_5 and 1·26 kg K_2O. Gallo

TABLE 5. YIELD OF TREES IN THE CASHEW GERMPLASM COLLECTION AT CASHEW RESEARCH STATION, VENGURLA (MAHARASHTRA)

No. of tree	Year of planting	Types/Hybrids	Average yield (kg/tree)									
			1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
162	1957	58 Types from Maharashtra*	0·186	0·346	0·541	0·526	0·948	0·813	1·271	2·870	3·860	4·020
157	1970	F_1 hybrid**	—	—	—	—	—	—	0·360	1·056	4·277	5·678

* Fertilised from 1972 onwards

** Fertilised from the beginning

(1964) recommended application of 15 kg farm yard manure or 1·5 kg oil cake, 1 kg superphosphate and 150 gm potassium sulphate per plant in the pit before planting. Lefebvre (1973a) recorded marked improvement in height and girth of the plants by treatment with 20 gm, N, 40 gm P and 36 gm K per plant at the time of planting and for 3 years thereafter. Application of N and P was essential for initial good growth, while for bearing trees, K in combination with N significantly increased the yield. According to Thomas Mathew (1982), a mature cashew tree requires 250 gm N, 125 gm P_2O_5 and 125 gm K_2O per year for high yield ; a young plant requires 84 gm N and 42 gm each of P_2O_5 and K_2O in the first year and 168 gm N and 84 gm each of P_2O_5 and K_2O during the second year of planting. The present fertiliser recommendations of the Central Plantation Crops Research Institute for cashew are 250 gm N, 125 gm P_2O_5 and 125 gm K_2O per tree annually to be applied in two split doses before and after the South-West monsoon (Table 6). The fertilisers may be applied in small trenches or basins around the trees.

TABLE 6. FERTILISER REQUIREMENTS OF CASHEW

Stages of growth	May-June (kg/ha)			September-October (kg/ha)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1st year	100	80	—	50	40	—
2nd year	50	40	30	50	40	30
3rd year	100	60	60	100	60	60
4th year onwards	125	60	60	125	60	60

Calton *et al*, (1961) showed that cashew requires little calcium, in addition to N, P, K.

Weeding

Weeding is necessary in cashew plantation to conserve available soil moisture especially during the early stages of growth.

Unlike other fruit trees, cashew is seldom pruned, but removal of dry and diseased branches is often necessary.

Intercropping

Till recently, intercropping in cashew plantation received very little attention. With the establishment of large plantation by the Forest Departments and cultivation of cashew in new areas in Andhra Pradesh and Orissa, intercropping is becoming more common. This would enable higher return from the plantations during the initial years. Once the canopy covers the area, it leaves no scope for intercropping because of the nature of foliage and complete shading of the interspace.

In Andhra Pradesh, legumes like horse gram, cowpea and groundnut are raised in cashew plantations as intercrop. Casuarina is another crop planted along with cashew. Teak and eucalyptus are grown in the plantations in Goa. Cashew, coconut and casuarina form a popular crop combination in the West Godavari district of Andhra Pradesh and in some coastal tracts of Orissa.

14.8 Flowering, Pollination and Fruit Set

The growth pattern of bearing tree consists of a generative flower flush and a vegetative flush. The vegetative flush, consisting of lateral shoots, always develops soon after the main crop has matured. Flowering is terminal and is universally preceded by the vegetative flush (Argles, 1969). Pattern of growth and flowering behaviour of cashew in West Bengal have also been studied by Chakravarty *et al.* (1980).

Flowering

The cashew tree normally starts bearing in three to five years and the inflorescence is an indeterminate panicle of polygamomonoecious type (Madhava Rao and Hassan, 1957 ; Damodaran *et al.* 1965). Each branch of the cluster bears a terminal flower subtended immediately by two or more bracts and from the axils of these bracts grow further bracted flower stalks. Damodaran *et al*, (1966) reported about 200 to 1600 flowers in a panicle. The ratio of perfect flowers to staminate varied from tree to tree (0·45 to 24·9). In cashew, normally there are three growth flushes and in South India the flower bud emergence commences by the middle of September and continue until the end of February, the main season being October-November. In West Bengal, panicles appear in December and flowering continues up to May. Late panicles bear few or no fruits.

Nambiar (1977) noted that the variation in the flowering season in cashew in different countries is related to altitude and latitude. Flowering appears in two or three distinct phases. Pavithran and Ravindranathan (1974) observed three distinct phases : (i) the first male phase with 19–100 per cent male flowers, (ii) the mixed phase with 0 to 60 per cent male flowers and 0 to 20 per cent hermaphrodite flowers, and (iii) the second male phase with 0 to 6·7 per cent male flowers. The mean duration of flowering was recorded as 84·8 days in which the duration of the first male phase was 2·4days, mixed phase 69·4 days and second male phase 13 days. The percentage of hermaphrodite flowers in the mixed phase was 22·2 and the mean fruit set was 4·6 (Anon., 1978). According to Nambiar *et al*, (unpublished data) the sequence of male and mixed phase, i.e., the sequence of production of male and hermaphrodite flowers, is a highly stable genetic character, and varies from tree to tree, and does not always conform to the

sequence given above. Chakravarty *et al*, (1981) reported maximum number of hermaphrodite flowers in panicles emerging in January and a gradual reduction till May. The panicles appearing in the southern side of the tree had the largest number of hermaphrodite flowers. It was also observed that partially mixed panicles and those appearing on one month old shoot had larger number of hermaphrodite flowers as compared to other types of panicles. More number of hermaphrodite flowers were also found in the middle portion of the panicle.

The scented small flowers are white to light green at the time of opening, later turning to pink. The flower is typically pentamerous (Copeland. 1961 ; Ascenso and Mota, 1972). There are five separate oblong, acute, imbricate sepals, erect and overlapping, so as to form a tube about as long as the pedicel (Copeland. 1961). There are five linear acute petals, alternating with the sepals. At anthesis, they are recurved, bringing the tips to the level of the receptacle.

Both the perfect and staminate flowers have 8 11 stamens of unequal size. One or two are large and the rest small, containing only very little well developed pollen grains. The anthers are basifixed dehiscing through a slit between the two pollen sacs of each lobe. The pollen grains are three-grooved, with the exine between the grooves finely pitted and are binucleate at maturity.

Ovary, style and stigma are present in both hermaphrodite and male flowers, but are rudimentary in the latter. The pistil is dorsiventral and the ovary is superior, laterally compressed with one end broader than the other end directed towards the large stamen. The ovary is unilocular and it contains a single anatropous ovule.

Pollination

The flowers start opening by 7 a.m. and continue up to 3 p.m., the peak of opening of the perfect flowers is between 9 a.m. and 2 p.m. in India and between 11.30 a.m. and 3 p.m. in Tanzania (Madhava Rao and Hassan, 1957 ; Damodaran *et al*, 1966 and Northwood, 1966). The stigma is receptive for about 24 hours before anthesis and continues to be so for about 48 hours after anthesis. The stigma becomes receptive as soon as the flowers open.

Damodaran *et al*, (1966) reported 94 per cent pollen fertility in the types studied. Pollination is reported to be carried out by flies, bees and ants as well as by wind. The strong scented flowers and sticky pollen emphasise the importance of insects over wind as pollinating agents.

Fruit set

The yield in cashew is low owing to small percentage of hermaphrodite flowers, low fruit set, heavy fruit drop, etc. (Hari Babu, 1982). Madhava Rao (1956) reported only 3 per cent fruit set, while Damodaran *et al*, (1966) observed 4 to 6 per cent fruit set under west coast conditions. Dasaradhi (1958) observed 6 to 12

per cent fruit set under east coast conditions, while Misra (1975) from Orissa reported 8 to 10 per cent fruit set.

Control of fruit drop and increase in fruit set by plant growth substances have also been tried. Sunder Rao *et al*, (1969) obtained 2 to 3 times more nut production over control by spraying 2, 4-D at 10 ppm either at the early or peak stage of flowering. Murthy *et al*. (1975) obtained more than 100 per cent increase in fruit set over control by spraying NAA at 10 ppm twice during the flowering period. In trials with IBA, IAA and NAA at different concentrations, Hari Babu (1982) recorded 265·3 per cent more fruit set over control by spraying with IBA at 50 ppm twice at pre- and post-bearing stages.

14.9 Growth of Nut and Apple

After fertilisation, the ovary grows considerably whereas the ovule enlarges slowly at the beginning, with the result the kernel does not fill the locule. The early growth of the ovule consists largely of the extension and curving upward of the chlazal end. Rao *et al*, (1962) observed that the nut reached maximum size in 30 days, hardened in the subsequent 10 days and declined in size by 10 per cent at harvest. From the fifth week onwards, when the growth of the nut ceases completely, the peduncle starts growing rapidly and outgrows the nut. The fruits ripen in about 60 days. As the season advances, the number of days required for the fruit to mature is reduced from 60 to 45 days. Chattopadhaya *et al*, (1983) also recorded that the nut grows much faster than the apple but in later stages, the apple increases in size more rapidly and soon out grows the nut. Protein content of the kernel increases steadily up to 40 days after fruit set and remains high till harvesting stage. The reducing and non-reducing sugars also increase up to 40 days, but decline sharply at harvest, while polysaccharide level cotinues to rise althrough. Bose (1964) observed that the growth of the apple is influenced by the presence of nut. If the nut is removed at the early stage, the apple fails to grow and dries. Application 2, 4-D and 2, 4, 5-T stimulated the growth of apple up to ripening without the nut.

The nut is grey coloured, kidney-shaped and contains a single kidney-shaped seed with membraneous adherent testa, semilunar cotyledons and short, hooked radicle. The fleshy peduncle, the cashew apple is juicy, sweet when ripe and is a rich source of vitamin C and sugar. The nut consists of an epicarp, mesocarp, endocarp, testa and kernel.

14.10 Pests and Diseases and Physiological Disorders

Pests

In India, more than sixty species of insect pests have been identified damaging cashew tree. Among various pests, the major ones are tea mosquito, stem

and root borer, leaf miner and leaf and blossom webber. Northwood and Kayumbo (1970) reported that in Tanzania, the sucking bugs (*Helopeltis schoutedeni* and *H. anacardii*), the theraptus bug (*Pseudotheraptus wayi*), the thrips (*Selenothrips rubrocinctus*), the bark borer (*Mecocorynus loripes*) and the defoliating caterpillar (*Nudaurelia bellina*) are the major pests.

Tea mosquito (*Helopeltis antonii*) : Tea mosquito causes severe damage to the tender shoots and inflorescence of cashew tree leading to heavy economic loss of the crop. The adult is a reddish brown mirid bug which usually appears at the time of emergence of new flushes and panicles. The bug lays eggs singly deep inside the tissue of tender shoots or floral branches. The pest population reaches its peak when the trees are in full blossom. Both the adults and nymphs of the bug suck sap from the tender shoots, floral branches, tender apples and even immature nuts. The tissues around the attacked portion develop necrotic patches and the adjacent patches coalesce resulting in drying up of the shoots. The fully affected panicles and shoots dry up. Crop loss due to tea mosquito attack was estimated to be more than 30 per cent.

The pest can be controlled by spraying Endosulfan 0·05 per cent applied as high volume spray or 0·1 per cent as low volume spray, at the time of emergence of new flushes (October) and panicles (December-January). Three rounds of sprayings are recommended depending upon the population fluctuation of the pest.

Stem and root borers (*Plocaederus ferrugineus*) : The stem borer is capable of killing the tree outright. The symptoms are the presence of small holes in the collar region, gummosis, extrusion of frass through holes, yellowing and shedding of leaves, drying of twigs and final death of the tree (Pillai, 1975 ; Pillai *et al*, 1976).

The adult is a dark brown longicorn beetle. It lays eggs in crevices of loose bark in the trunk. The grubs that hatch out bore into the bark and feed on the sub-epidermal and vascular tissues and the tissues are tunnelled in irregular directions.

The pest can be controlled effectively by mechanical removal of the immature pests in the early stages of infestation and swabbing the trunk and root zones with BHC 0·1 per cent suspension. The pest is also controlled by injecting Carbaryl or Pyrethrin piperonyl butoxide (both 1 per cent solution) into the tunnels or by applying Phorate granules (10 gm/tree) or aluminium phosphide (1-2 tablets/tree) to the tunnels. However, the trees in the middle and advanced stages of infestation cannot be saved. Such trees beyond recovery should be cut and removed from the plantation. Phytosanitary measures are very important to get effective control of the pest.

Two other species of longicorn beetles, *P. obesus* and *Batocera rufomaculata* were also observed infesting cashew trees. The bark borer (*Indarbela tetraonis*)

is another pest present in most of the plantations. This can be controlled by the mechanical removal of the larvae and swabbing with 0·1 per cent BHC.

Leaf miner (*Acrocercops syngramma*) : Leaf miner generally appears in the post-harvest and post-monsoon flushes. The caterpillars of the silvery grey moth mine through the tender leaves and severely damage them. The tortuous markings appear first and later as the thin epidermal peel of the mined areas swell up, blistered patches develop. Abraham (1958) estimated the damage to be 26 per cent in severely infested tracts whereas Basu Choudhuri (1962) recorded 75–80 per cent damage of the leaves.

The pest can be effectively controlled by spraying 0·05 per cent Fenitrothion at the time of emergence of new flushes. Endosulfan (0·05%) spraying against tea mosquito infestation will take care of this pest also.

Leaf and blossom webber : There are two species of leaf and shoot webbing caterpillars, *Lamida moncusalis* and *Orthaga exvinacea*. Of these the former is a major pest, especially in the coastal districts of Andhra Pradesh. The caterpillars web the shoots and inflorescences together, remain inside and feed on them. Spraying 0·2 per cent BHC or 0·05 per cent Fenitrothion or Endosulfan at the time of emergence of new flushes immediately after the monsoon was recommended for the control of the pest. Ayyanna, Subbaratnam and Rao (1977) reported that Carbaryl 0·15 per cent and Malathion 0·15 per cent were the most effective insecticides against the pest.

Other pests

Other pests like the defoliating caterpillars—*Cricula trifenestrata*, *Metanastria hyrtaca* ; shoot tip caterpillars—*Hypatima* (*Chelaria*) *haligramma*, *Anarsia epotias* ; leaf and flower thrips—*Selenothrips rubrocinctus* and *Rhipiphorothrips cruentatus* ; leaf beetles and weevils—*Monolepta longitarsus* and *Apoderus tranquebaricus*, etc., also appear sporadically at times. Most of these pests can be controlled by the sprays against tea mosquito.

Diseases

Cashew tree is attacked by a number of diseases. Among these, the most important ones are inflorescence blight, die-back or pink disease, damping off of seedlings, and anthracnose disease.

Inflorescence blight : The disease is characterised by the drying of floral branches. The incidence of the disease mainly occurs when cloudy weather prevails. Studies carried out at the Cashew Research Station, Ullal, showed that the inflorescence blight was caused by fungi like *Gloeosporium mangiferae* and *Phomopsis anacardii* in association with tea mosquito, *Helopeltis antonii*. However, subsequent investigations (Nambiar *et al*, 1973) revealed that the disease was primarily caused by tea mosquito and the fungi associated with it were only

secondary saprophytic colonisers. This important finding helped to eliminate fungicide from the spray schedule against this malady.

Die-back or pink disease: This is a common disease caused by *Corticium salmonicolor* (*Pellicularia salmonicolor*) prevalent during the rainy season. The affected branches initially show white patches on the bark and a film of silky thread of mycelium develops on the branches during the monsoon. Later, the fungus develops a pinkish growth which represents the spore form. In due course, the bark splits and peels off and the affected shoot starts drying up from the tip. Control measures include pruning of the affected branches below the spot of infection and destroying them, protecting the cut surface by application of Bordeaux paste and giving prophylatic sprays of Bordeaux mixture (1%) twice in May-June before the onset of South-West monsoon and the second in October.

Damping off of seedlings: Under conditions of poor drainage in the nursery, the disease occurs. Kumararaj and Bhide (1962) recorded severe loss of the seedlings due to this disease. Different fungi cause damping off in different areas. *Fusarium* sp., *Pythium* sp., *Phytophthora palmivora* and *Cylindrocladium scoparium* have been reported as causative organisms from Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra (Anon., 1960; Susamma Philip, 1973). The fungi attack either the root or the collar region or both of the seedlings. Control measures include provision of adequate drainage in the nursery and drenching the beds/bags with Ceresan 0·1 per cent or Bordeaux mixture 1 per cent.

Anthracnose: Agnoloni and Giuliani (1977) reported that the anthracnose disease causes severe crop loss in Brazil. *Colletotrichum gleosporioides* is the causative organism (Singh *et al*, 1967), which penetrates the dead tissues. The fungus enters the fruit through the stigma in the flower stage itself. The disease is severe when rainfall coincides with the flowering season. Singh *et al*, (1967) recommended the control measures for the disease which include removal of the affected parts and spraying the plant with 3 : 3 : 50 Bordeaux mixture and provision of wind break by growing tall trees like casuarina, eucalyptus, etc., to arrest spread of the disease by wind-blown spores.

Other diseases

Other lesser important diseases affecting the cashew tree are: (i) decline caused by *Pythium spinosum*. The disease causing defoliation and drying of twigs in the dry season can be controlled by the application of Chestnut compound in the soil at the base of the tree; (ii) many types of leaf spots have been reported on cashew (Batista, 1957; Anon., 1960; Guba, 1961; Early and Punithalingam, 1972); grey blight (*Pestalotia microspora*; *P. dichaeta*); red leaf spot (*Phyllosticta* sp.); brown leaf spot (*Colletotrichum gloeosporioides*), ferruginous spots (*Phomatospora anacardicola*), leaf spot caused by *Phomopsis anacardii* and red rust caused by *Cephaleuros mycoides*. All these diseases can be controlled by spraying with 1 per cent Bordeaux mixture; copper oxide (0·3%) or Benlate (0·3%). The sooty

mould caused by *Capnodium* sp. can be controlled by spraying fish oil rosin soap 1·5 kg in 100 litre water, followed by 2 per cent starch solution.

The shoot rot and leaf fall caused by *Phytophthora nicotianae* var. *Nicotianae*, powdery mildew on the blossom caused by the fungus *Odium* sp., leaf rot disease caused by *Cylindrocladium quinquiseptatum*, gummosis caused by *Pellicularia salmonicolor*, *Diplodia natalensis* and *Ceratocystis* sp. and a few minor diseases of apples and nuts have been reported in cashew.

Physiological disorders

Lefebvre (1973 b) reported little leaf disease in cashew characterised by small, rolled leathery leaves. He attributed this to zinc deficiency and found that application of Zn to the soil or by foliar spray alleviated the symptoms. Adams *et al*, (1977) recorded iron deficiency in Kenya and this caused leaf necrosis.

14.11 Harvesting

Harvesting and collection of nuts are done over a period of 10 12 weeks. Where apple is not collected, the fruits may be allowed to fall on the ground and nuts collected periodically during the first 4-6 weeks. Later most of the nuts are collected in one or two major harvests. Towards the end of the season nuts can again be collected from the ground.

14.12 Yield

The yield of nut per tree varies enormously from 1 to 45 kg per year. At present, the average yield in India is only 2·1 kg/tree/year. Kerala records the maximum average yield (5·5 kg), followed by Karnataka (2·1 kg) and Andhra Pradesh (2·0 kg). An average yield 43 kg has been obtained from a tree at Vengurla. Exceptional high yielder at Bapatla yielding 90 kg of raw nut/year and record yield of 125 kg reported from a single tree from Kottarakkara (Kerala) show the gap between realised yields and potential yields (Anon., 1979). Purseglove (1968) mentioned an average yield of 386–454 kg per year per acre.

14·13 Processing

Processing of cashewnuts is the recovery of kernel from raw nuts by manual or mechanical means. There are about 250 cashew processing factories in India with a capacity of 500 tonnes per annum. Processing consists of moisture conditioning, roasting, shelling, drying, peeling, grading and packaging.

Conditioning involves sprinkling of water on dried nuts to bring to an optimum moisture level of 15–25 per cent. Roasting makes the shell brittle. The

PROCESSING METHODS

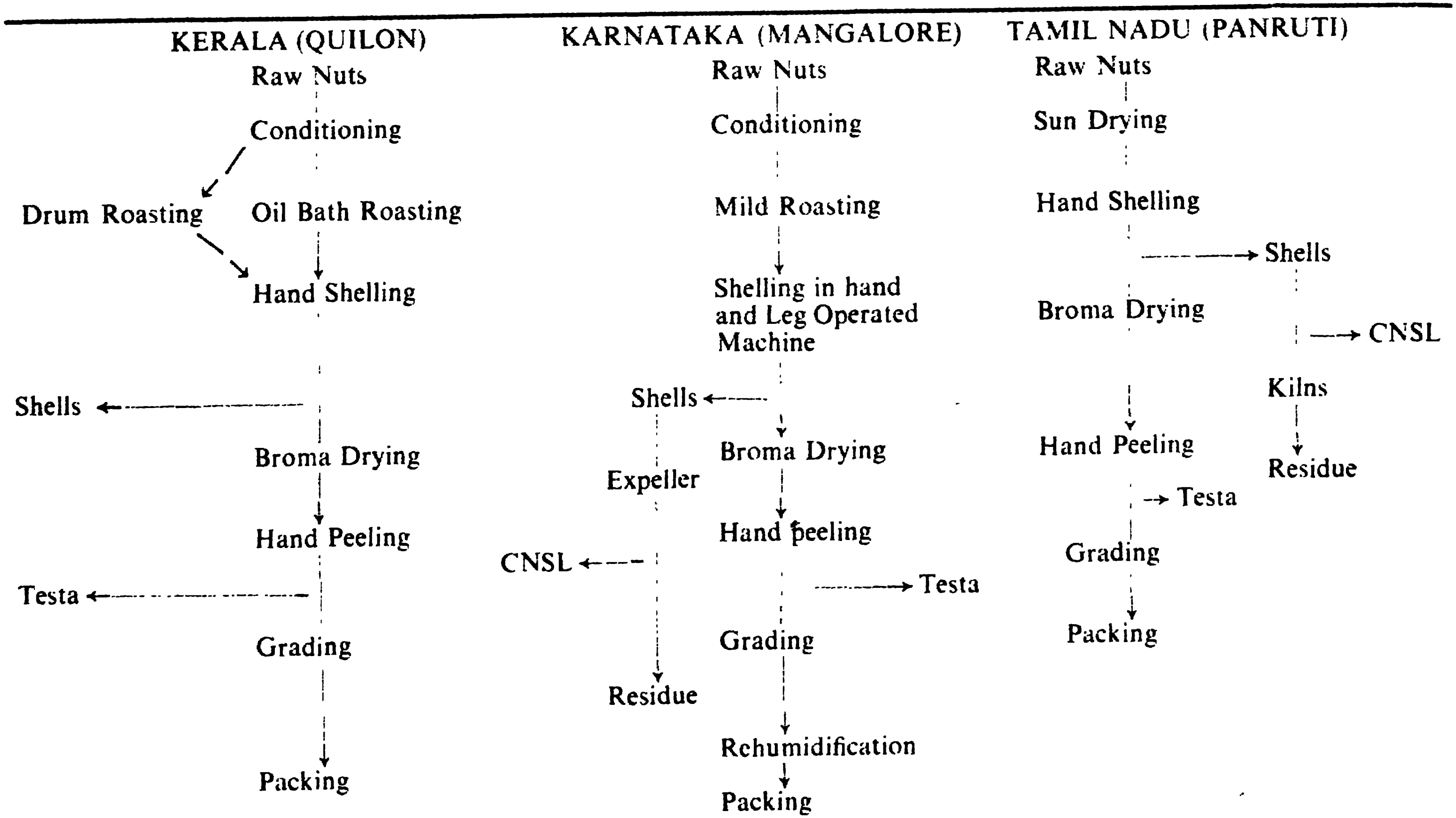


Fig. 1

two important methods of roasting are—(i) drum roasting and (ii) oil bath roasting.

In drum roasting, the rate of shelling and the out-turn of wholes are high. The main disadvantage of this method is the loss of CNSL.

In oil bath roasting, the shell gets heated and cell walls get separated releasing oil into the bath. The oil is recovered by continuous overflow arrangement. The technique followed in different factories varies to some extent with regard to temperature and time of roasting.

Shelling is usually done manually except in some units where hand and leg operated shelling machines are used. The kernel is scooped out by means of a sharp needle. After shelling, the kernels are dried to reduce the moisture and to loosen the adhering testa. Most commonly used driers are the Broma driers (Lakshminarayana *et al*, 1965 ; Russell, 1969). After drying for about 6-12 hours, the peeling is done by hand. Next stage is the grading of kernels on the basis of specification for exportable grades. The wholes are size-graded on the basis of number of kernels per kg. Packing is usually done in 10 kg capacity tins which are subsequently evacuated and filled with carbon dioxide. In order to overcome the possible overdrying, a rehumidification step is introduced before packing. The processing methods adopted in different states in India are given in Fig. 1.

Mechanical processing has been started recently in Africa. However, manual operation as done in India gives a considerably higher yield (90-95%) of wholes as compared to mechanical processing.

14.14 Packaging and Marketing

Packaging

For export purposes, cashew kernels are usually packed in cases of 11·35 kg (25 pounds) net weight and two such cases are put in a wooden case. The kernels for internal markets are also packed in tins of 9 to 11 kg capacity. For retail selling, smaller packing varying from 0·5 to 6·5 kg are also adopted. Instead of tins, many firms use polythene bags as the container for packing smaller quantities of kernels.

Marketing

Marketing of raw cashewnut has not yet been organised in a systematic way except in Kerala. The Directorate of Marketing and Inspection in the Ministry of Agriculture had framed grade standards for raw cashewnuts. The specifications are based on moisture, void nuts, number of nuts/kg, immature and damaged nuts. The quality of raw nuts produced in Kerala is superior to that produced in other parts.

The producers are generally persons of small means and there are a number of intermediaries operating between the primary producer and the processing unit. Hence it is necessary to establish village cooperative cashew marketing societies with cashew growers as members. In Kerala, the Government appointed the Kerala State Marketing Federation Limited as the sole agent for cashew marketing, which in turn appointed Cooperative Societies throughout the state as sub-agents for the procurement of raw nuts. The Government fixes the procurement prices (price received by the grower) as well as the issue prices (price paid by the processing unit) of raw cashewnuts from time to time.

Though the regulated marketing system has been already enacted in many states for major agricultural commodities, only in Tamil Nadu, raw cashewnut arrives in significant quantities in the regulated markets. The regulatory measures improve the efficiency of marketing system and help to reduce the gap between the producer's price and the price paid by the consumer.

14.15 Breeding and Varietal Improvement

Cashew was introduced into India in the Goa region and Malabar Coast during the 16th century (de Costa, 1578 : van Linschoten, 1598). It is most likely that the original introduction must have been nuts from a few trees and thus had a limited genetic base from which all the present day varieties in the country have been developed. This may be the reason for low variability in the cultivated cashew in India. The same assumption holds good for all other countries except South American countries, particularly Brazil, where it is supposed to have originated (Johnson, 1972). Variability observed at present with respect to flowering period, sex expression, percentage of fruit set, size, shape, colour, smell, taste and astringency of apple and size, shape and specific gravity of nuts (Morada, 1941 : Madhava Rao and Hassan, 1957 ; Cordoba, 1967 ; Northwood, 1967 ; Morton, 1970) may be due to segregation of inherent heterozygosity.

Systematic collection, conservation, cataloguing and evaluation of germplasm of cashew was attempted only very recently. Over one thousand collections including 69 exotic collections from Brazil, South Africa, Mexico, Tanzania, Malaysia, Nigeria, Tanganyika and Sri Lanka are being evaluated for yield and associated characters and quality of nuts and apple, at the Centres of Cashew Research in India. Germplasm assemblage in different cashew research centres and the promising types identified are given in Table 7.

Cashew tree is polygamous and monoecious, with staminate and hermaphrodite flowers appearing in the same panicle. Though both cross- and self-pollination take place in cashew, the structure of the flowers is more conducive to cross-pollination than self-pollination. Being a cross-fertilised crop, the most effective and shortest approach for its improvement will be to identify high yielding

TABLE 7. GERMPLASM ASSEMBLAGE AND PROMISING SELECTIONS AT DIFFERENT CASHEW RESEARCH CENTRES

Research Station	No. of accessions			Promising types identified	
	Exotic	Indigenous	Total	Selection No.	Average yield per year (kg)
Bapatla	22	159	179	129	40·0
				56	20·0
				1	42·0
				273	28·8
				3/3	13·0
				9/8	12·5
Vridhachalam	8	169	177	M 25/1	16·4
				M 26/2	15·9
				M 3/4	15·0
				M 16/3	14·8
				M 10/4	7·6
				M 44/3	7·8
				M 76/1E	6·0
				M 6/1	7·0
Vengurla		116	116	Veng. I	19·7
				Veng. II	40·0
Vittal	–	163	163	--	
Anakkayam /Mannuthy	39	151	190	NDR-2-1	19·5
				UL 271	17·0
				NLR-2-1	14·0
				BLA-139-1	34·0
				BLA-273-1	21·4
				BLA-39-4	15·0
				K-10-2	13·5
				K-28-2	13·4

mother trees on the basis of yield, structure of the plant, intensity of branching, flowering and fruit set, quality of nut and apple and to multiply them vegetatively or through seeds after progeny testing. Based on progeny testing, prepotent trees could be identified and clonal progenies of these prepotent trees could be planted in seed gardens to collect clonal seeds for distribution to farmers. Different methods of grafting and budding could be adopted for propagating these superior genotypes as well as for upgrading poor yielding trees in a plantation raised from clonal seeds.

Success of any breeding programme depends on the selection procedures adopted. The characters under selection should be present in high heritability. Practically, no information is available on the genetics of different characters in cashew, though there have been attempts to correlate yield with ratio of bisexual flowers, short and synchronised flowering, branching and flowering intensity and fruits per panicle. The yield of nuts from a tree is proportional to the number

of fruit-set, and the total number of flowering shoots per unit area (Anon., 1975). The weight of nut has a positive correlation with height of seedlings and number of leaves and negative correlation with girth and internodal length (Anon., 1978). Northwood (1966) observed that trees which produced large number of nuts had small nuts unsuitable for cashew trade. Observations recorded at Cashew Research Station, Ullal indicated that heavy yielding trees were more likely to produce medium-sized nuts (120-130 nuts/kg) and hence medium-sized nuts should be preferred in selection. Medium-sized nuts also had higher percentage of germination than either heavy or light nuts (Madhava Rao and Hassan, 1956 ; Shetty and Bhatkal, 1965). Northwood, (1967) observed that the seedlings from high density groups grew better and had higher yields during the first three harvesting years, though this difference disappeared by the 4th year.

Galang and Lazo (1936) stressed the significance of association of growth features with bearing tendency in cashew. They found that leaf area was associated with productivity. According to Morton (1970) trees exhibiting sprawly growth produced only a tangled mass at base and dead branches and the maximum flowering was seen in trees with erect growing habit. This observation is in agreement with the extensive type of branching described by Dasaradhi (1958). Madhava Rao (1974) found a positive correlation between yield and percentage of bisexual flowers. He observed 3 per cent fruit-set under open pollination and 55 per cent by hand pollination. He concluded that it was highly desirable to select types with higher percentage of perfect flowers for increasing the production in cashew. Damodaran (1979) reported positive correlation, though weak, between the proportion of bisexual flowers and gross yield of nuts on young trees.

A comparative yield trial with seedling progenies of 16 selections selected from Cashew Research Stations, Bapatla (Andhra Pradesh), Anakkayam (Kerala), Vengurla (Maharashtra) and Vridhachalam (Tamil Nadu) are being evaluated in a replicated multilocation trial at all the above centres and at Vittal (CPCRI). The yield data from 6th to 8th year of their orchard life show that the seedling progenies of M 10/4 and M 44/3 of Vridhachalam and BLA-139-1 of Anakkayam are superior to the progenies of other selections and further, the data suggest that these lines could be used, with advantage, for production and distribution of clonal seed.

A study of photosynthetic efficiency of different types of canopy in cashew in relation to the yield of nuts would help to review the present practice of allowing unlimited growth canopy in cashew tree. Some of the methods suggested for limiting the plant canopy to have maximum photosynthetic efficiency are (i) adopting a closer spacing, (ii) pruning annually to restrict the plant canopy and (iii) pruning all the branches, which do not receive adequate sunlight (Nambiar, 1977).

Hybridisation

In India, breeding work for the improvement of cashew has been in progress at many Cashew Research Centres. Selection of parents has been based on yield, size of nut, synchronised flowering phase and a high shelling percentage. The hybridisation technique consists of clipping of all the staminate flowers in a panicle and emasculating either all the stamens or the single functional stamen from the perfect flowers and bagging with a butter paper. Anthers from selected trees are collected next morning and pollen is dusted on the stigmatic surface of the emasculated flowers by a brush and the butter paper replaced in position.

TABLE 8. PERFORMANCE OF PROMISING HYBRIDS AT CASHEW RESEARCH CENTRES

Research Station	Hybrid	Parentage	Percentage of perfect flowers	Weight of 100 nuts (gm)	Average yield for 5 years (kg)	Shelling percentage
Anakkayam/ Mannuthy	H-3-17	T. 30 × Brazil-18	13·3	655	17·8	26·2
	H-3-19	T. 30 × Brazil-18		-	22·7	29·8
	H-4-7	T. 30A × Brazil-18	12·3	620	12·3	25·3
	H-3-7	T. 30 × Brazil-18	—	—	12·9	27·3
	H-3-12	T. 30 × Brazil-18	—	—	13·6	27·6
Bapatla	2/11	T. No. 1 × T. No. 273	13·2	530	17·1	27·5
	2/12	T. No. 1 × T. No. 273	6·9	500	19·4	25·7
Vengurla	No. 5	Ansur-1 × Vetore-56	—	—	18·2	27·6
	11	Midnapore Red × Vetore-56		—	20·4	30·7
	19	do	—	-	19·9	32·2
	24	Ansur Early × Mysore Kotekar 1/61	—	—	23·3	31·0
	38	WBDC-V × Ansur-1		—	15·4	—

Hybridisation work carried out at Anakkayam (Kerala) has shown that whenever an exotic parent was involved, the progeny showed better performance than crosses between local types. These results are in agreement with the

TABLE 9. GROWTH MEASUREMENTS AND YIELD DATA FOR SELFED, OPEN POLLINATED AND HYBRID TREES IN CASHEW

Treatments	Girth (cm) taken at three intervals			Height (cm) taken at three intervals			Spread in cm taken at three intervals			Mean yield of nuts per tree in kg for			
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1971-72	1972-73	1973-74	1974-75
Selfed plants	40·00	58·8	59·8	345·42	456·00	505·00	345·08	428·40	486·60	0·550	0·627	0·286	1·298
Hybrids	50·83	61·9	62·2	442·83	466·60	512·20	412·08	437·80	489·90	1·263	2·391	1·072	2·450
Open pollinated	47·75	63·7	66·7	432·50	540·20	596·70	382·92	529·10	575·10	0·500	1·116	0·461	1·547

established concept that hybrid vigour is best manifested in crosses involving parents with greater genetic diversity. Hybridisation work carried out at other centres (Vengurla, Bapatla and Vridhachalam) also confirm the expression of hybrid vigour in cashew. In Vengurla, 80 out of 157 hybrids planted in 1970–71 gave an yield ranging from 10–15 kg nuts per year and 5 among them recorded more than 20 kg nuts in the 8th year of their orchard life (Table 8). Comparison of the performance of hybrids with open pollinated and selfed progenies also showed the superiority of the hybrids over others (Table 9).

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15

SAPOTA

U. V. SULLADMATH and M. A. NARAYANA REDDY

Sapota (*Achras zapota* L.) is a delicious fruit introduced from tropical America. It is also known as sapodilla or chiku in India, it is mainly cultivated for its fruits, while in South-East Mexico, Guatemala, British Honduras and other countries chickle is commercially produced. The unripe fruits and bark yield a milky white latex which solidifies on exposure to air and this forms the base for making chickle. Immature fruits are astringent, while ripe fruits are sweet smelling and delicious. The mature fruits are also used for making mixed jams and they provide a valuable sources of raw material for the manufacture of industrial glucose, pectin and natural fruit jellies. They are also canned as slices.

In the Dutch East Indies, the young leafy shoots are frequently eaten raw or mixed with other vegetables like lab-lab and consumed as a vegetable after steaming.

15.1 Composition and Uses

Sapota when fully ripe is delicious and is eaten as dessert fruit. The pulp is sweet and melting. The usual practice is to eat only the pulp. The fruit skin can also be eaten since it is richer than the pulp in nutritive value (Gopalan *et al*, 1981). The sapota fruits are a good source of sugar which ranges between 12 and 14 per cent. The pulp is also made into sherbets and halwas (Singh *et al*, 1963).

The constituents in ripe sapota fruits are given in Table 1.

TABLE 1. COMPOSITION OF RIPE SAPOTA (per 100 gm of edible portion)

Constituents	
Moisture	73·7 gm
Carbohydrate	21·4 gm
Protein	0·7 gm
Fat	1·1 gm
Calcium	28 mg
Phosphorus	27 mg
Iron	2 mg
Ascorbic acid	6 mg

In the coastal areas, the fruits are soaked in melted butter for a night and eaten in the morning. It is said to be an excellent preventive against biliousness and febrile attacks. In the West Indies, seeds are known to be aperient and diuretic and the bark is reputed to be tonic and febrifuge. In Guinea, the bark is used as a tonic and antipyretic. In Kampuchia, the bark is considered as an astringent and febrifuge. The decoction is given in diarrhoea and in paludism (Kirthikar and Basu, 1975).

15.2 Origin and Distribution

Sapota is a native of Mexico, and Central America, and now widely cultivated throughout tropics. Sapota was cultivated in the West Indies long back and Oviedo who was there from 1513 to 1525 considered it as the best of all fruits. It was taken to the Philippines in the early days by the Spanish and from there it spread westwards to Malaysia and other countries (Purseglove, 1968). It is not known when it was first introduced into India (Singh *et al.* 1963), but the sapota cultivation was taken up for the first time in Maharashtra in 1898 in a village named Gholwad (Cheema *et al*, 1954). The states that are growing sapota on a commercial scale in India are Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, West Bengal, Punjab and Haryana (Cheema *et al*, 1954; Purseglove, 1968 and Singh, 1969). The total area under sapota in India is 2000 hectares (Shanmugavelu and Srinivasan, 1973).

15.3 Species and Varieties

Species

Sapota belongs to family Sapotaceae. It's botanical name is *Achras zapota* L., *Manilkara achras* (Mill) Fosberg is a synonym.

Varieties

There are several varieties of sapota in India. They are grouped under four types based on the habit of the tree, i.e., nature of branches and colour of foliage. They are as follows :

Trees with erect growing habit

Branches appear in whorls ; foliage deep green and broad and oval. Fruits large in size with a smooth and yellow skin. Pulp is butter like and sweet.

Fig. 1. A sapota shoot with leaves and flowers

Trees with drooping habit

Branches appear in whorls ; foliage light green, narrow and elliptical. Fruits small with rough brownish skin and pulp of inferior quality.

Trees with spreading habit

Branching irregular ; foliage deep green in colour, broad and oval. Fruits with smooth and yellow skin. Pulp is butter like and sweet.

Trees with spreading habit

Branching irregular ; foliage light green in colour, narrow, elliptical. Fruits with rough skin. Pulp inferior.

Each of these groups may further be subdivided into two sections based on shape of fruits, either round or oval.

A good table sapota should have a few seeds with melting sweet pulp. Thick skinned, hard-fleshed varieties with sandy texture are considered inferior. The

varieties need to be standardised. The following are the different varieties grown in India :

Kalipatti : It is a leading variety of Maharashtra, Gujarat and North Karnataka. It has dark green, broad and thick leaves. Spreading branches. Fruits are oval shaped, less seeded with a sweet, mellow flesh of excellent quality. Fragrance is mild. Each fruit has 1-4 seeds. Fruits appear singly. The main harvest is in winter.

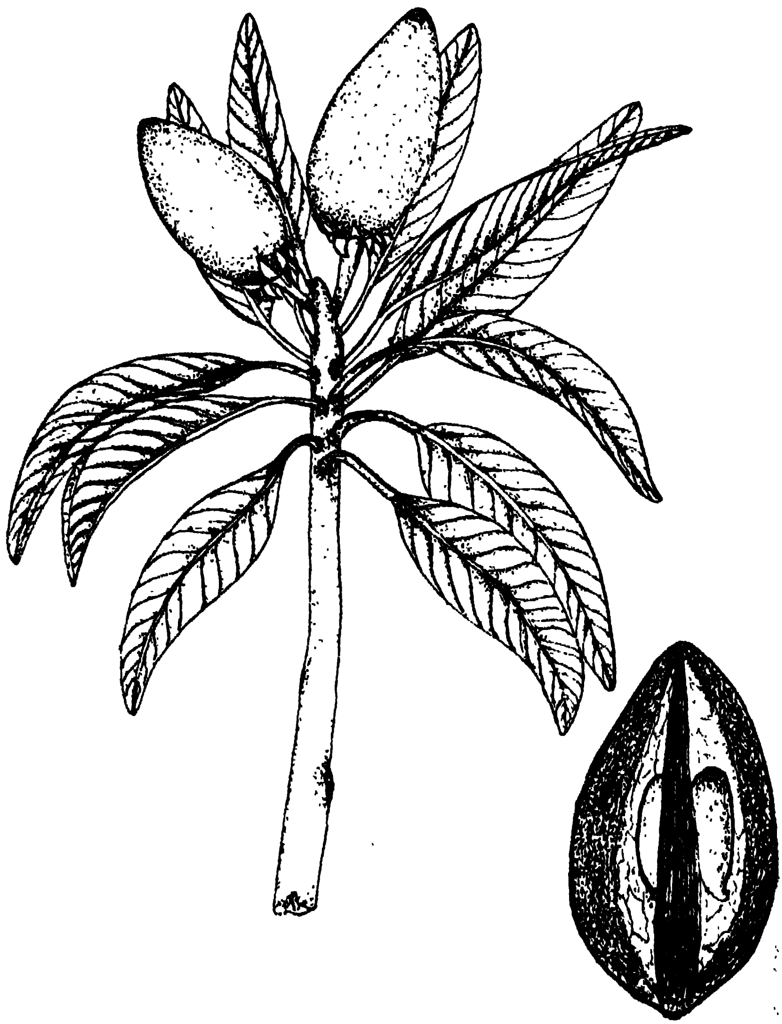

Fig. 2. Kalipatti sapota in bearing and L.S. of the fruit showing seeds

Chaatri : It is similar to Kalipatti but the branches have a drooping nature similar to that of an umbrella. The branches appear in all directions horizontally in whorls. The leaves are light green in colour. Fruits are similar to Kalipatti in appearance but the fruit quality is not as good as in Kalipatti. It is a fairly good cropper but not as heavy as Kalipatti. It is also an important variety in Maharashtra.

Dhola Diwani : This variety is found in Maharashtra. It has light green leaves and whitish oval fruits that are harvested in summer. Fruits are superior in quality.

Long : This is another variety found in Maharashtra. It has narrow and small leaves. Fruits are thin and long and very sweet. Because of its poor bearing it is not grown commercially.

Bhuri or Bhuripatti : It has thick foliage but the leaves are medium-sized ; bearing is medium. Fruits are large in size and of good quality.

Jingar : It is a medium-sized tree with small leaves and fruits appear in bunches.

Vanjet : It is a sterile or male type : slow growing in nature. Knots are seen on the branches. Roots emerge from these knots. It is a shy bearing variety but fruits have a good quality. This is found in Maharashtra.

Pala : It is a popular variety in Andhra Pradesh and Tamil Nadu. The fruits are small to medium-sized and oval or egg-shaped, with apex broadly pointed and are very sweet. The bearing is heavy and fruits are borne in clusters. The fruit has thin skin and of good flavour.

Kirthabharthi : It is a popular variety of Andhra Pradesh. The fruits are small to medium-sized and oval or egg-shaped. On the rind 4-6 ridges are seen. Fruit skin is rough, medium thick and buff coloured. Pulp is sweet. Fruit apex is rounded. The fruits can be transported to distant markets.

Dwarapudi : The fruits resemble those of Cricket Ball but smaller in size. It is popular in Andhra Pradesh. Fruits have a sweet pulp and are in great demand.

Jonnavalasa Round : Fruits are small to medium in size and round in shape. It is a popular variety in Vizianagaram district of Andhra Pradesh. A small cavity is seen at the stalk end and has 10-11 ridges. The pulp is firm, cream coloured and very sweet.

Cricket Ball : Also known as Calcutta Large. It is grown in Tamil Nadu, Karnataka, Maharashtra, West Bengal and Andhra Pradesh. The leaves are light green. This bears the largest-sized fruits which are round in shape. Pulp is gritty and granular and not very sweet. It is a shy bearer ; does well in arid climate and at elevations of 300 m.

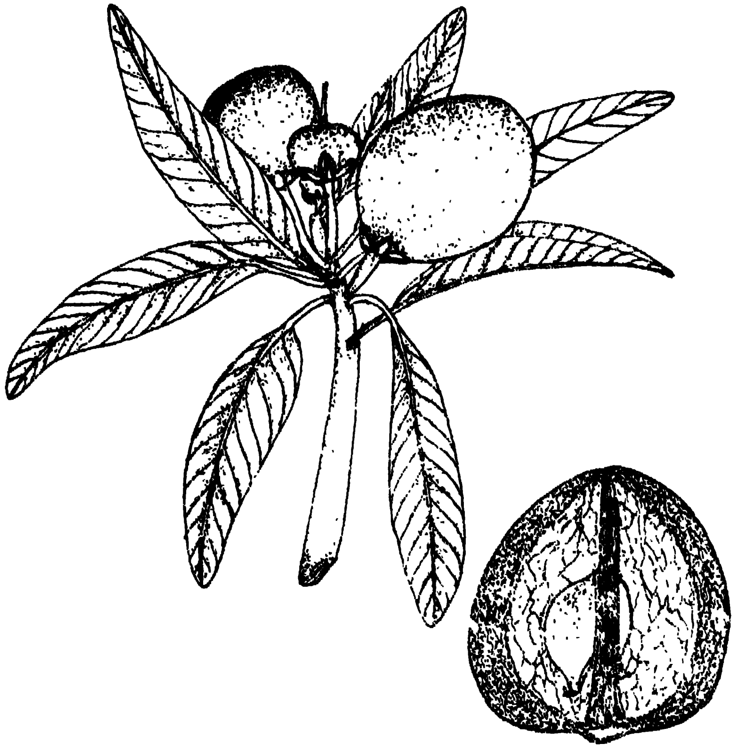

Fig. 3. Cricket Ball sapota in bearing and L.S. of the fruit showing seed

Oval : The fruits are small to medium-sized and oval or egg-shaped. Pulp is coarse grained and less sweet. It is a shy bearing variety.

Vavi Valasa : It is grown in the coastal districts of Andhra Pradesh. The fruits are oval.

Bangalore : It bears large, oval-shaped fruits with nine ridges running from base upwards. The apex is round. Pulp is gold coloured with a tinge of musk melon. In taste the fruits are medium-sweet. This variety is grown in some parts of Andhra Pradesh.

Calcutta Round : It is commercially grown in West Bengal, Karnataka and other states. The foliage is light green in colour. Fruits are large but the flesh is gritty and of moderate quality. It is susceptible to leaf spot disease.

Jonnavalasa I : It is a popular variety of Andhra Pradesh. It bears medium-sized fruits with rough skin which is thin and without ridges. The pulp is cream coloured and sweet.

Jonnavalasa II : It is also grown in Andhra Pradesh. Fruits are medium-sized, ovate with a prominent depression near the stalk end. The fruit skin has

buff colour with whitish flakes and eight marked ridges. The flesh colour is like that of a musk melon with a golden tinge towards the cavity.

Baramasi : It is a popular variety in West Bengal, Bihar and Uttar Pradesh. The fruits are medium in size and roundish. It does not, however, bear throughout the year as the name indicates.

Pot Sapota : Fruits are borne when the plants are still in pots and hence the name. This bears small-sized, oval fruits with pointed apex and no ridges on the surface. The fruit is exceedingly sweet with good flavour.

Gavarayya : It bears small-sized fruits with one shoulder drooping and the other raised. On the fruit surface, 8-10 marked ridges are seen. The flesh is soft, melting and very sweet. It is grown in Andhra Pradesh and Tamil Nadu.

Thagarampudi : It bears medium-sized round or oval-shaped fruits with a flat base ; fruit skin is thin and rough without any ridges. The flesh is buff coloured, streaked, melting and juicy. It has a very sweet taste and good for export. It is grown in Tamil Nadu.

Ayyangar : It is a rose-scented variety and bears large-sized fruits, round or obovate with a small cavity at the stalk end. The flesh has a pinkish tinge towards the core and sweet. Flavour is pleasant. Ridges are not prominent, skin is very thick and buff coloured. It is grown in Tamil Nadu.

The other varieties that are cultivated on a smallscale are Pilipatti, Jumakia and Mohan Gooti in Maharashtra ; Badam in Tamil Nadu and Gede and Guthi in Andhra Pradesh.

In Florida, USA, varieties Prolific and Brown Sugar have been found to be good producers and used for general planting. Others like Modello and Russel have been propagated in the nursery trade but do not bear fruit heavily or regularly. Addley, Adelaide, Big Pine Key, Black, Jamaica No. 4, Jamaica No. 5, Martin, Saunders and Seedless have been found unfruitful in some areas and hence not recommended. Others like Tikal are being tested. All these are selections from open pollinated populations.

15.4 Soil and Climate

Soil

Sapota is a hardy tree and can be grown on a wide range of soils. Drainage is most important. There should not be a hard pan in the sub-soil. In sandy soils, the plants are subjected to uprooting by strong winds since they lack strong anchorage. Deep and porous soils are preferred. In soils underlined with hard *murum* in the sub-soil at a depth of 60-90 cm, the plants make a good growth in the first seven to eight years but when the roots touch this hard layer the leaves turn pale colour and the fruit size diminishes. In black cotton soils or clay soils

there is very poor drainage and aeration during the rainy season and in summer cracks develop in the soil and as a result the smaller roots are damaged. Sapota can tolerate the presence of salts in the soil or in irrigation water to some extent.

The most ideal soils are deep alluvium, sandy loams, red laterites and medium black soils. Sapota is sometimes planted in dry river beds with alluvial soil.

The unsuitable soils are those underlined with hard rock or lime content, yellow coloured and sticky soils. Presence of high lime content in the soil causes the loss of green matter in the leaves and such plants die within a short time.

In South India, particularly in the Western Ghats of Karnataka, sapota is grown successfully on gravelly laterite soils (Anon., 1975 ; Cheema *et al*, 1954 ; Choudhury, 1954 ; Singh, 1967 ; and Singh *et al*, 1963).

Climate

Sapota is a tropical fruit crop and can be grown from sea level up to 1200 m. It prefers a warm and moist weather and grows in both dry and humid areas. Coastal climate is best suited. In South India, it is grown on the hills up to 1000 m. At higher altitudes the fruit quality and tree health suffer. Areas with an annual rainfall of 125-250 cm are highly suitable. Rain or cloudy weather during any part of the year does not do any harm to fruit set. The optimum temperature is between 11 and 34 °C.

In northern parts of India, young plants undergo injury during winter months by frost. Fully grown trees can withstand mild frost for a short period. This is the reason for restricting the sapota growing to only the sheltered pockets of the northern parts of India– in Punjab, Haryana, Uttar Pradesh. Sapota does well on the plains of North India but irrigation and protection in summer months are necessary. A high temperature above 41°C during summer causes drying up of stigmatic fluid, flower drop and fruit scorching. In severe cases, leaves and fruits undergo scorching. Dry and strong winds also cause damage to flowers, leaves and fruits (Anon., 1975 ; Choudhury, 1954 ; Gopalaswamiengar, 1970 ; Narasimham, 1966 ; Puttarudraiah, 1980).

15.5 Propagation

Seed

Sapota is propagated by both seed and vegetative methods. In the earlier days, seedlings were used for planting but they have some disadvantages such as slow growth, very long pre-bearing age of 8-10 years, growing to a huge size or height and showing too much of variation or not being true to type. In South Florida, this is used to be a common method (Cheema *et al*, 1954 and Sayed, 1962).

Seeds are collected from elite trees and sown in pans or beds with light sandy soils as germinating medium and watered at regular intervals. Shanmugavelu (1970) found that GA_3 promoted the percentage of germination and increased the growth of seedlings.

Vegetative propagation

The vegetative method has many advantages such as being true to type, earliness in bearing, dwarf or easily manageable size of the trees, favourable rootstock may influence and improve bearing. Among the vegetative methods, the most important are air-layering or gootee, ground layering, pot layering, inarching, and budding. Recently, attempts have been made to multiply this plant through tissue culture also.

Layering

Air-layering or gootee : Sapota is a difficult-to-root plant. Many factors are known to affect the rooting ability of this plant. Vigour of the shoot has been found to be one of the important factors in this regard. The loss of rooting ability over a period of change from juvenility to maturity is a recognised fact. In rooting of air-layers in sapota, the invigorated shoots produced as a result of beheading a grafted tree possess a better rooting ability than mature shoots (Uthaiah *et al*, 1977).

This method is most common in Maharashtra, Gujarat, Karnataka, Tamil Nadu, Andhra Pradesh. In this method, it is possible to get a sizable plant in a short time but mortality is high and the root system is shallow. Such trees are likely to be uprooted when heavy winds are experienced in sandy soils. In Maharashtra, it is believed that air-layered plants give more granular fruits and that some varieties do not strike roots easily.

The best time for air-layering is the beginning of rainy season. High humidity prevailing during the monsoon facilitates rooting. One to two years old, 45-60 cm long mature branches of pencil thickness (0·6 to 1·0 cm) with plenty of healthy dark green foliage are selected at a suitable height. Thicker branches are not suitable since the bark does not peel off easily. With the help of a sharp knife a ring of bark 2·5 to 3 cm in length is removed carefully. Over this moist rooting medium such as sphagnum moss or vermiculite is covered and wrapped with plastic or polythene film. In about 3 months roots emerge from the upper ring of the air-layered branch. Some times, the medium becomes dry and it should be moistened.

The air-layers should not be separated from the parent tree outright. When roots have fully formed a 'v' shaped cut or notch is made in the layered branch 10-15 cm below the layered portion and it is deepened at an interval of fifteen days and finally severed after 6 weeks from the date of first cut. Singh *et al*, (1962)

reported that rooting percentage in air layer of sapota increased with a mixture of IBA and NAA at 10,000 ppm.

Ground-layering : Ground-layering is not a commercial method but is followed in Maharashtra to some extent. The branches close to the ground level are made use of. This is easier than air-layering. On the branch, 3 cm long cut is given up to half the thickness against the growing point in the form of a tongue and a piece of stick is inserted in the tongue to prevent it from uniting and finally the layer is buried in a heap or mound of soil. The layer is weighed down with a sufficiently heavy stone or pegged to keep the branch in position. The mound of soil is kept moist. Monsoon (June-July) is the ideal time and can be done up to September. Rooting takes place in about 2 to 3 months and in about another one month they can be separated.

Pot-layering : This is followed in Maharashtra and northern parts of Karnataka. A shallow earthen pot with 'v' shaped cuts on the rim is used to insert the branch to be layered. This pot is known as 'parali'. It is filled with a moist mixture of equal quantities of farm yard manure and soil. The ringed branch is inserted in between the crotches and covered with moist medium over which a small flat stone is placed to prevent it from being dislodged due to wind. Watering is done regularly. In about two months roots appear and in another 1 2 months the branches are separated and potted.

Root stock

Use of proper rootstock is important in grafting or budding, since the slow growth of seedling, rootstock becomes a limiting factor for rapid multiplication of the desirable forms in large number. The use of rootstock also poses certain problems such as incompatibility and undesirable or adverse effects. Often the incompatibility affects fruit quality after several years.

The different rootstocks used are :

1. Sapota seedlings (*Achras zapota*)
2. Rayan or khirni or pala (*Manilkara hexandra* or *Mimusops hexandra*)
3. Adam's apple (*Manilkara kauki* or *Mimusops kauki*)
4. Mahua (*Madhuca latifolia*)
5. Mee tree (*Bassia longifolia*)
6. Star apple (*Chrysophyllum cainito*)
7. Miracular fruit (*Sideroxylon dulicifolium*)

Sapota seedlings take a long time to attain a suitable size for grafting. In Andhra Pradesh, Adam's apple is used as a rootstock. In Sri Lanka, both Mee tree and Miracular fruit are used as rootstocks. Mee tree seedling as rootstock grows quickly and develops deep tap root but exhibits incompatibility, by over growing the scion, Mahua produces bigger plants but fruits are poor in quality due to the presence of an alkaloid saponin. Of all the rootstocks

rayan (*Mimusops hexandra*) has been found to be the most suitable rootstock for sapota (Singh, 1969). It, however, shows variability in the rate of growth of seedlings. Some varieties are vigorous growing, while others are comparatively slow growing. It is more a compatible rootstock than *Madhuca longifolia*.

Results of rootstock trials on sapota conducted at the Fruit Research Station, Gandevi in Surat district of Gujarat indicated that sapotas on rayan rootstocks were far superior to those raised on sapota seedlings and from air-layers. In terms of yield also the trees grafted on rayan gave 50 per cent more than that on air-layers and twice that on sapota seedling stock. The trees on rayan stock were found to be healthy and strong even after four decades (Cheema *et al*, 1954 ; Ram and Sahai, 1962 and Sayed, 1962). Further studies would be necessary to confirm the suitability of other species such as *Chrysophyllum cainito*, *Manilkara kauki* and others in respect of vigour of seedlings, graft compatibily, fruit quality, and their economic value.

Raising of rootstocks : The rayan fruits are small, oval and sweet. They are washed to get rid of the pulp in water and dried under shade and sown. For easy and quick germination, the seeds are soaked in water for a night. They are sown in raised seed beds or pots. The seeds germinate in about 4 weeks and when they are about 15 cm high they are potted in small pots or 'madkis'.

In nature, self-sown seedlings occur in plenty and such seedlings are also made use of as rootstocks. In Ratnagiri district in Maharashtra and Surat district in Gujarat, such self-grown seedlings of rayan from the forest areas are collected for potting. All the side growths are removed up to a height of 30 cm from ground level to get a clean and straight stem. When they attain a thickness of 1 cm they are used for grafting or budding.

Grafting

Comparatively longer time for rooting and high percentage of mortality in layer necessitates resorting to grafting which is the most popular and commercial method of propagation of sapota. Some varieties do not strike roots easily by gootee or layering and hence have to be propagated by grafting.

Inarch grafting : It is the commercial method of propagation practised over 40 years. Various rootstocks such as sapota seedlings, khirnee or rayan and mahua seedlings are used. The rootstocks are raised in pots. The scion remains attached to the parent tree till the union is complete and if the scion branches are high, the stock plants are placed on bamboo platforms or any such other device.

Side grafting : The advantage in this method is that the top of the rootstock need not be removed. The scion is prepared in the form of a wedge with one side slightly longer than the other. An incision is made into the stock at an angle of 20-25° and the scion is inserted into this incision. Both are properly tied and

sealed at the graft union. After union the top of the stock plant is cut just above the point of union (Singh *et al*, 1963).

Rejuvenation of damaged trees : Sapota trees damaged by diseases or rodents near the root system or the crown can be rejuvenated by inarching. A few enterprising, leading growers in Maharashtra and Gujarat adopted this method with considerable success (Gandhi, 1963 and Sayed, 1962). In this, rayan seedling of 3–4 years of age are planted close to trunk around the tree and when fully established are grafted to it by bridge grafting. It is believed that trees raised from air-layers and supported by rayan seedlings need less irrigation and the cost of irrigation can be reduced as the rayan roots go deep into the soil (Gandhi, 1963 and Sayed, 1962).

Budding

This is a cheaper, easier and more efficient method. A single bud is employed for budding. In Sri Lanka, this method is followed by using *khirni* rootstocks. This method can be adopted all over the coastal regions of the country where climate is moist and rainfall heavy. For budding, May is the best month. In this, a flap of bark is eased out in the form of a tongue and the bud along with a little bark attached to it is inserted underneath the flap and covered keeping the scion bud exposed. After union, the bud starts developing and the top of the seedling is cut a little above the bud union.

Comparison in the performance of air-layers and grafts

Plants from air-layers are very shallow rooted and most of the roots concentrate in the top 30–45 cm of soil. These can thrive in both deep and shallow soils. Fruits from such trees have been found to be sweeter with mellow pulp.

Grafts have comparatively deeper root system and most of the roots are concentrated between 60 and 90 cm from the ground surface. The grafts on rootstocks like *khirni* require at least 90 cm deep soil for good growth. Grafts on heavier soils have been found to give more yield than air-layers.

In Poona, under dry and light rainfall conditions, the grafts on *khirni* rootstocks were found to be vigorous in the first two years, but they developed chlorosis later in places where calcarious sub-soil was present, while grafts on chiku seedlings were slow growing as compared to layers during that period but later started giving good crops.

In the Telangana area of Andhra Pradesh, grafts on *chalka* soils derived from granite rock which become hard on drying showed poor growth of plants and low yields. At Kodur Fruit Research Station, grafts on *khirni* rootstocks have made a good growth and have given more yield than those on *Bassia longifolia* stock.

In Gujarat also, the grafts on *khirni* rootstocks under low rainfall and deep loamy soil conditions have proved better in respect of yield than air-layers and

grafts on chiku seedling stocks (Singh *et al*, 1963). In Maharashtra, air-layers are preferred to grafts because of the reason that grafts bear more granular pulp (Cheema *et al*, 1954). A thorough comparative study of propagation by grafting and budding seems to be necessary to study their relative performance over a long period.

Tissue culture

Mesocarp, endosperm and embryo culture have been attempted in sapota on modified Murashige and Skoog medium supplemented with various levels and combinations of auxins and nutrients. The studies indicated that both types of callus required coconut milk (10 per cent by volume) in synergistic combination with 2, 4-D at 2 mg/litre for growth. The addition of kinetin at 1 mg/litre enhanced proliferation. Sucrose was optimal at 2 per cent. Mesocarp produced callus only. In embryo and endosperm culture, the cotyledons proliferated while endosperm alone produced callus but no organogenesis occurred (Bapat and Narayanaswamy, 1977).

15.6 Cultivation

Selection and preparation of land

A location, free from water stagnation should be selected and all the vegetation be removed. It is then ploughed two or three times and levelled. Undulated land should be divided into terraces depending on the topography of the land and levelling is done.

If the soil is poor, it would be advisible to grow a green manure crop and plough it in so as to improve its physical and chemical conditions before planting operations are taken up.

Establishing a live windbreak

A strong windbreak should be established by planting tall and thick growing trees on the windward side or on all sides of the orchard. Seedlings of mangoes, jamun and tamarind can serve as windbreaks, but these trees are slow growing and have a spreading habit of growth. While silver oak or casuarina being quick and erect growing make an ideal windbreak. The plants for wind break may be planted at 1·5 to 1·8 m apart in the row. The windbreak is helpful in avoiding damages due to strong winds and particularly in sandy soils. To avoid root competition, a trench 90 cm deep and 15 cm wide may be dug between the first row of sapota plants and 3-4 m away from the row of windbreak plants.

Preparation of pits and planting

Pits of the size of 60 cm^3 or 100 cm^3 are prepared at a distance of 8-10 m both ways depending upon the planting material and the soil. In low rainfall areas and soils with low fertility closer spacing is followed, while in heavy rainfall tracts and fertile soils a wider spacing is recommended.

The top 30 cm soil is kept separately on the one side of the pit, while the remaining is kept on another side. The pits are exposed to weather for a month or two. The best time for making pits is during April-May. In Maharashtra, there is a practice of filling the pits with brush wood or rice husk and burning it and the pits are kept exposed till monsoon. After one or two showers, the pit are filled with top soil and farm yard manure or compost in equal quantities. In Maharashtra, at the time of filling pits 30 kg of sheep manure and 12 kg of bone meal are put at the base of each pit and the rest is filled with top soil. One or two showers later will help to settle the soil in the pit.

The best time for planting is during early monsoon. Grafts, budded plants or layers are planted one in each pit in the centre and care should be taken to see that the graft or bud joint is at least 15 cm above the ground level. The soil around the roots is gently and firmly pressed and stakes are provided to avoid wind damage.

The plants are then watered.

Protection from sun scorch and frost

Young plants are likely to be damaged due to the scorching sun, dry, hot, wind and frost. In Karnataka, northern districts such as Raichur, Gulbarga, Bidar and Bellary experience very high temperatures in the middle of summer causing scorching of foliage. Young plants are covered with coconut leaves to protect against the direct sun. In North India, young plants are protected against the hot sun and frost by putting dry grass thatches on top and three sides excepting the south-east side for sunlight.

Training and pruning

In sapota, a strong central stem is necessary and in air-layers most of the branches are put forth very near the ground level. In the beginning, the basal branches help in developing a thick central stem and hence care must be taken to maintain proper distribution of branches on all sides. But later, with an advance in age, the lower most branches weigh down to ground level and become unfruitful. Sapota, in general has a well balanced distribution of branches and the tree crown assumes a uniform shape. There is no necessity of pruning every year.

All the growths that appear on the rootstock below the graft or bud joint must be removed. After 3 to 4 years of planting, the lower most branches up to a height of 60–90 cm may be removed. Similarly, overshaded and crowded branches are also to be removed.

In sapota, new growth and flowering occur simultaneously and it is a mixed type of bearing habit. Flowers and fruits appear in the leaf axils in the new growth and hence pruning of branches should not be done.

Irrigation

Though sapota can tolerate drought conditions to some extent, yet it responds well to irrigation. Young plants are watered regularly during dry season and long breaks in the monsoon ; in winter and summer at an interval of 6 to 12 days (Singh *et al*, 1963). In Maharashtra, young plants are given irrigation once in eight days from October onwards till monsoon starts. Protective irrigation is given during first two seasons in Karnataka for better establishment of plants (Anon., 1975). Insufficient irrigation results in dropping of a large number of flowers leading to a loss up to 40 per cent in yield (Cheema *et al*, 1954).

In the beginning, small basins are made and hand watered but as the plant grows in size, the size of the basin is also widened. In coastal Gujarat, there is a practice of raising 0·5 m high mounds of earth around the trees to protect them from strong winds and to conserve moisture (Singh, 1969).

Manuring and fertilisation

For healthy growth and good quality fruits, manures and fertilisers should be applied in the required dosages. When intercrops such as banana are grown in sapota they get heavy fertilisation indirectly since bananas are given manures and fertilisers. Besides this, the pseudostems are cut and incorporated into the soil (Singh, 1969). In Andhra Pradesh, on an average, each tree is given 100 kg farm yard manure, 6 kg castor cake and 2 kg superphosphate per year (Narasimham, 1966). In Maharashtra, the sapota trees are given yearly application of manures and fertilisers and a one-year old tree gets 20 kg farm yard manure and 400 gm castor cake and this dosage is increased every year by 4 kg and 400 gm respectively. Thus a ten-year old tree gets 40 kg farm yard manure and 6 kg of castor cake. For bearing trees of ten years and more, each tree is given 2 kg bone meal also (Singh *et al*, 1963). Application of superphosphate to provide phosphorus is said to improve the size of fruit in old orchards. The doses of fertiliser recommended in Karnataka are given in Table 1 (Anon., 1975) :

TABLE 1. FERTILISER SCHEDULE FOR SAPOTA

Age of the plant	*N*	*P* (*in gm*)	*K*
1–3 years	50	20	75
4–6 years	100	40	150
7–10 years	200	80	300
11 years and more	400	160	450

Farm yard manure is applied at 40 kg per year.

In a fertiliser trial conducted at Navsari, Gujarat on Kalipatti variety with three levels of N, P and K (0, 45 and 80 gm for each year of age and stabilised to 0, 450 and 900 gm in the tenth year) the results indicated that during the first two years there was no significant effect on yield but in the subsequent years treatment effects were significant and with an increase in the level of nitrogen a linear increase in respect of both yield and growth of the trees was found, while phosphorus and potash were not effective (Chundawat *et al*, 1981). Patil *et al*, (1981) in a trial at the Mahatma Phule Krishi Vidyapeeth, Rahuri in Maharashtra found that application of increased levels of nitrogen resulted in a significant linear increase in plant growth, size, number and total weight of fruits at harvest, while phosphorus and potash were effective only at lower levels. Nitrogen at 1 kg per tree resulted in a significant improvement in total soluble solids and reducing sugar and the leaf N content increased significantly with increasing levels of applied nitrogen. There is a necessity of application of nitrogen beyond 1·5 kg per tree and optimum economic doses of P_2O_5 and K_2O are 0·45 kg and 0·58 kg respectively. If phosphorus is lacking the fruits become hard and small.

Leaf sampling techniques in sapota var. Kalipatti was standardised (Chavan and Patil, 1979) and the best time for sampling of leaves for nitrogen, potash, magnesium and manganese analyses was July and for phosphorus, calcium, iron and zinc it was during April-January.

Time and method of application

For best results, the manures and fertilisers should be applied in two split doses. In Maharashtra and Karnataka, they are first applied in the beginning of monsoon in dry zones and at the end of south-west monsoon in heavy rainfall areas. These are applied in a shallow circular trench 15 to 22 cm deep, 15 cm wide and 60-90 cm away from the trunk. Split application is followed in the trees that are bearing heavy crops. After application fertilisers are covered with top soil and irrigated.

Intercropping

Sapota has a long pre-bearing age and till the trees cover the entire area with their leaf canopy intercrops can be grown. This period may be as long as 10 years and short duration fruits like banana, papaya or vegetables can be profitably grown. Leguminous vegetables and pulses like cowpea, cluster bean, lima bean, peas, etc., and pigeon pea and others benefit in several ways.

Weeding

Weeds compete for nutrients and moisture and hence should be removed frequently. When intercrops are grown they may not be a problem during that period and in such cases the basins only are kept free from weeds.

15.7 Flowering, Floral Biology, Pollination and Fruit-set

Flowering

Sapota starts bearing small crops from second or third year of planting but economical yields can be obtained from seventh year onwards. Under tropical conditions, flowers are seen almost throughout the year. However, there are two main seasons of flowering and hence two harvesting seasons.

Floral biology and Pollination

Sambamurthi and Ramalingam (1954) studied the blossom biology of the sapota at Coimbatore and indicated that pollination is by wind and unpollinated flowers failed to set fruits. Madhava Rao and Khader (1960) found that among five different varieties, studied at the same campus, one was highly self-sterile and the fertility of the remaining four was very low as indicated by pollination tests. No evidence of bud pollination or parthenocarpy was noticed. The existance of inter-varietal relationship in regard to pollen compatibility was apparent in the varieties studied.

Hayes (1957) found that in an isolated sapota tree not more than half a dozen fruits were set at a time under Allahabad conditions. Nalawadi *et al*, (1977) studied the floral biology of sapota at the Agricultural College, Dharwar, Karnataka, in Kalipatti, Cricket Ball, Calcutta Round and Oval varieties. Three seasons of flowering were recorded with maximum in June, while in October and March the flowering was less ; peak of anthesis was found at 4 a.m., in all the varieties and maximum stigmatic receptivity on the day of opening of flowers. The shape of pollen grains was roundish and their colour being yellowish with an average pollen size of 16·25 μ. Acetocarmine stainability was 96·3 per cent in local varieties and in others 97·6 per cent. Maximum pollen germination of 15 per cent was observed in sucrose solution at 48 hours of incubation period and all the four varieties were found to be cross-pollinated.

Fruit set

The fruit set is the most potent factor which determines the yield. Problems of shedding and low fertility in sapota were reported by Cheema *et al*, 1954 ; Hayes, 1957. In variety Kalipatti, 22 per cent natural fruit set was observed and the maximum fruit drop occured immediately after fruit setting (Patil and Narwadkar, 1974). The fruit drop during the course of fruit development was, however, meagre. It was also observed that the flowers situated at the base of inflorescence opened and set earlier. Such early set fruits developed rapidly and the remaining which set relatively late, often dropped down.

Improvement of fruit set

Self-unfruitfulness is seen in stray plants and problem of pollination becomes difficult (Singh, 1969). Use of growth regulators has been found to be beneficial. In an attempt to get higher fruit set and retention of the set fruits, several growth substances such as gibberellic acid, Ethrel, Cycocel, and Planofix (a NAA preparation) and SADH were tried at Bhubaneshwar in Cricket Ball variety (Das and Mahapatra, 1975). These chemicals were applied in spray solutions before flowering and again at the pea stage. Of all the regulators, SADH at 100 ppm resulted in the highest fruit set and Planofix at 300 ppm resulted in the highest fruit retention and largest fruits, followed by 100 ppm GA_3.

In similar studies made at the Gujarat Agricultural University, Navsari, of the two growth regulators tried at 25 to 100 ppm as spray at flowering and at fifteen day intervals, NAA resulted in a better fruit set than GA_3 (Rahtod and Amin, 1981).

15.8 Fruit Growth and Development

In an investigation at the Agricultural College, Dharwar, Karnataka on the periodical changes in the fresh weight of developing fruits of var. Kalipatti, a double sigmoid pattern of growth was noticed with two periods of active growth and one period of retarded growth (Rao, 1978). From the first to twelveth fortnight the fruits showed 23·6 per cent of total weight at maturity and in the second stage only 14·4 per cent. The third stage of fruit development from the seventeenth to twenty first fortnight had maximum amount of growth of 62 per cent in terms of fresh weight increase. The total time taken from fruit set to maturity was ten months and a half and there was a long lag phase and very slow growth rate at the initial stages of fruit development.

The time taken from flower bud initiation to harvest varies with the climatic and other conditions. Purseglove (1968) reported that fruits take 4 months to mature from the date of flowering, while Sulladmath and Rao (1979) reported that the time taken from fruit set to maturity in Kalipatti variety was more than 10 months. Sometimes, the trees bear flowers continuously in several flushes at short intervals throughout the year, as a result, fruits also mature at different times. Fruits that mature during March-May are generally better in quality.

Influence of seed on fruit growth

The diversity in the shape of fruit in sapota is an interesting feature. Varieties such as Calcutta Round and Cricket Ball produce exclusively round fruits, while Badam, Oval, Vavi Valasa and others produce oval or elliptical fruits. Kalipatti and Chhatri varieties have a special feature of producing both round and elliptical

fruits, simultaneously on the same tree during the same season. A correlation was worked out between the shape index and seed number per fruit and between fruit weight and seed number. A significant negative correlation (−0·92) between the shape index and the seed number per fruit was observed (Rao, 1978). The seed number per fruit ranged from 1 to 9 and the round fruits had more number of seeds (3·99) than oval (1·52). The shape index was higher for oval fruits (1·53) than round fruits (1·11). The regression analysis suggested that for every decrease in the seed number by a value of one, there was an increase in the shape index by a value of 0·20 and the fruit tended to be oval in shape. The fruit shape may also be governed by the way of distribution of seeds around the placenta. In round shaped fruits, the seeds were more uniformly distributed around the placenta as compared to oval fruits. A positive correlation (0·77) was present between the number of seeds per fruit and fruit weight. Round fruits were heavier (101·0 gm) than oval fruits (69·7 gm). This indicated the existence of a hormonal influence of seeds on fruit development.

15.9 Pests and Diseases

Sapota crop is affected by insect pests and diseases and necessary plant protection measures should be taken up in time.

Pests

Stem borer (*Indarbela tetraonis*) : This is a small beetle. The grub is stout and bores into the bark of the trunk making circular galleries and feeds on the living tissue of the inner bark. The presence of the insect can be detected from the chewed bark thrown out of a hole in the trunk. The borer can be traced by cutting dead bark along the hollow tunnels with a knife. This insect has been reported from Tamil Nadu, Karnataka and other places (Abdul Ravoof, 1964 ; Puttarudraiah, 1980).

The insect is killed by thrusting a stiff wire into the tunnel. If it is deep inside the wood the hole is plugged with a wad of cotton wool dipped in kerosene or BHC 0·1% and plastered with wet mud. By this, the borer gets suffocated and dies within the tree.

Scale insects (*Pulvinaria psidii*) : These are green or brown scales, oval shaped with a slight twist at the front end. The characteristic feature is the presence of an inverted loop on the body. These infest along the sides of mid-rib and surface of leaves and on the tender twigs. They suck the sap.

Spraying a suitable insecticide such as Dimithoate or Malathion at 30 ml in 18 litres of water effectively controls the pest. Two or three sprays are necessary (Anon., 1975).

Leaf webber (*Nephopteryx eugraphella*) : It feeds on buds, leaves and young fruits. Application of Carbaryl 0·15% and Malathion 0·15% are very effective.

Mealy bug (*Phenacoccus icerjoides*) : These are small, oval with a cottony white waxy covering on their body. They stick to the under surface of leaves and base of fruit stalks. They suck the sap and secrete large quantities of sugary substance. Spraying of Dimithoate at the rate of 30 ml in 18 litres can effectively control this pest.

Leaf miner : It is a tiny caterpillar and the adult is a grey coloured moth. It mines into the surface of young leaves and makes them curl. Infected leaves show glistening irregular galleries or mines on the leaf surface. The tiny caterpillars are seen inside these galleries. Such leaves get distorted, dry up and fall.

One or two sprays of Dimithoate (30 ml in 18 litres of water) or Malathion (36 ml in 18 litres of water) provide satisfactory control.

Flower bud eating caterpillar : Flowers and flower buds are damaged to a considerable extent by a small caterpillar, resulting in their shedding. In studies at the Agricultural College, Dharwar, Karnataka and Coimbatore, Tamil Nadu, this insect was found to be responsible for shedding of a large number of flowers. Farooqui *et al.* (1973) recorded a heavy flower drop for a period of three months and it was as high as 88 per cent, at bud, flower or fruit set stages.

This can be controlled by the same measures as for leaf miner.

Bark eating caterpillar (*Indarbela* sp.) : This bores into the stem bark and the excreta along with fibrous material hang down outside the bark. This can be effectively controlled by giving one or two sprays of Dimithoate (30 ml in 18 litres of water).

Fruit borer (*Virachola isocrates*) : The young fruits are affected. The latex comes out and crystallises. This insect can also be effectively controlled by the same measures as for leaf miner.

Diseases

Leaf spot : This disease caused by a fungus *Phaeophleospora indica* was first reported from Dharwar by Chinnappa (1968). It is characterised by numerous, small pinkish to reddish-brown spots with whitish centres. In recent years, it is becoming severe. Sohi and Sridhar (1972) and Sohi and Prakasn (1972) recommended monthly sprays of 0·2 per cent Dithane Z-78 for most effective control, while treatment with 0·5 per cent Blitox was less effective under Bangalore conditions. Prasad *et al*, (1979) in a trial on the comparative resistance of several selections and varieties in sapota at the Agricultural College, Dharwar, Karnataka, found that CO 1 and Cricket Ball were more resistant to *Phaeophleospora indica* leaf spot disease. The varieties CO2 and Kalipatti also showed tolerance, while Calcutta Round was most susceptible. Leaf spot incited by *Pestalotia* sp.

(Wilson *et al*, 1970) and *Glomerella cingulata* (Sohi and Om Prakash, 1972) has also been reported in sapota.

Sooty mould : It is also a fungal disease developing on the honeydew like excretion by scale insects and mealy bugs. This a common disease in India, incited by *Capnodium* sp. and adversely affects the photosynthetic function of leaves and disfigures the fruit. This can be controlled by spraying starch solution (100 gm in 18 litres water). On drying this forms thin flakes and drop off. Spraying with 40 gm Zineb in 18 litres water checks the disease.

Flattening of branches : The branches become flattened and this has been attributed to a pathogen *Botryodiplodia theobromae* (Khurana and Singh, 1973). This has been recorded in South India, coastal area of Maharashtra and Gujarat and in such trees the fruit set and yields are adversely affected. The affected branches produce small, dry, hard and shrivelled fruits. During summer months these flattened branches may give rise to normal branches. As yet no suitable control measure has been found out.

15.10 Harvesting

Sapota is a climacteric fruit and it improves in quality after harvesting but immature fruits should not be harvested. The fruits to be harvested must be fully matured and the maturity can be judged by several external symptoms as mentioned below :

(i) Fruits at full maturity develop a dull orange or potato colour.
(ii) A mature fruit when scratched, lightly shows a yellow streak instead of a green streak which is a sign of immature condition.
(iii) Brown scaly material disappears from the fruit surface as the fruits approach full maturity.
(iv) As the fruit matures, the milky latex content is reduced.
(v) The dried spine like stigma at the tip of fruit falls or drops off easily when touched.

The fully matured fruits are harvested with the stalk intact, individually by giving a twist and collected without bruising. The fruits thus harvested are spread in a thin layer on bamboo mats under shade for an hour or two. To avoid bruising of fruits they are better collected in gunny bags and lowered to the ground carefully. The peak harvest periods are January-February and May–June in the west coast of Maharashtra ; March–May and September–October in Andhra Pradesh and March–May and September–October in Karnataka.

15.11 Yield

The yield depends upon several factors such as the age of the tree, variety, agro-climatic conditions of the locality, nutrition and plant protection measures.

In round and large-sized varieties, such as Cricket Ball and Calcutta Round, less number of fruits are obtained, while in others with oval or long fruits more number of fruits are possible but their size is small. In very prolific bearers like Pala, the number of fruits are much more. On an average, a 3-year-old tree can yield about 100 fruits ; a 5-year-old tree, 250 fruits ; a 7-year-old tree, 700 fruits ; a 8-year-old tree, 800 fruits ; a 10-year-old tree, 1000 fruits ; a 11-year-old tree, 1500 fruits ; a 15-year-old tree, 2000 fruits ; and a 30-year-old tree, 2500 to 3000 fruits per year (Anon., 1975 ; Gandhi, 1963 ; Gopalaswamiengar, 1970 ; Narasimham, 1966 and Singh, 1969). Purseglove (1968) also reported similar yield from 30-year old trees of sapota.

15.12 Ripening and Storage

Ripening

Fruits ripen in about 5 days after harvest at room temperature and the ripening period depends upon the variety, stage of maturity and temperature. They ripen well at 12-14°C. Lakshminarayana and Subramanyam (1966) reported a slow ripening in 9-13 days after harvest in fruits of Calcutta Round. The fruits are spread on mats or floor in a single layer. They emit a sweet smell and become soft.

To reduce the time taken for ripening a few growth regulators can also be made use of. By treating with the growth regulator solutions, a uniform ripening is possible and the most commonly used chemical is Ethephon. Sastry (1970) reported that fruits ripened after 2 days of storage with ethylene, while the untreated ones and those wrapped in gunny bags took 7 days for complete ripening.

In a study at the Tamil Nadu Agricultural University, Madhava Rao *et al*, (1971) reported that when fully mature fruits of sapota were dipped in 5000 ppm Ethephon before storage at room temperature or kept in airtight chambers in the presence of Ethephon at 500–5000 ppm with added NaOH, ripening occurred within 2 days. While there was no change in colour or TSS in the fruits, a marked reduction in the phenolic contents was noticed and there was an increase in total sugars, reducing sugars and titrable acidity due to the treatment.

In a similar investigation, Das and Mahapatra (1976) at Bhubaneswar, Orissa found that Ethrel was effective in early ripening of sapota fruits without any adverse effects. Fruits dipped in Ethrel (250–7500 ppm), 2, 4-D (5-15 ppm) or wax emulsion (3–9 per cent) or kept in dry paddy straw indicated that those treated with Ethrel ripened in 3 days as compared to only 26 per cent in untreated controls. The other substances were equally effective with slight difference. Ethrel brought about enhancement of total soluble solids as well as total sugars.

Soni *et al*, (1981) at Udaipur, Rajasthan were able to enhance the ripening process of Cricket Ball variety of sapota fruits through pre- and post-harvest application of Ethrel. The fruits were treated at maturity, 15–30 days before

expected maturity both on tree and after harvesting. The fruits were stored under ordinary light and dark conditions for ripening. There was no significant effect on the ripening of fruits in the pre-harvest application. However, in the detached fruits application of 1000 and 2000 ppm Ethrel at 15 days before and at full maturity and their subsequent storage under ordinary light proved to be the most appropriate treatment for inducing early and uniform ripening. The treated fruits showed an improvement in taste, TSS, ascorbic acid, reducing, non-reducing and total sugars and a reduced acid content. Ethrel resulted in ripening of all the fruits within 71 hours of treatment without any deterioration in organoleptic quality and physico-chemical components.

Storage

The storage period of ripe sapota fruits depends on the respiration, relative humidity, temperature, enzymic activity and carbon dioxide contents. The fruits are climacteric and the respiratory peak occurs at the same time or one or two days after peak ethylene production. At the optimum storage temperature of 20 °C, the storage life could be increased by removing ethylene and adding 5–10 per cent CO_2 to storage atmosphere. Excess relative humidity or high concentration of CO_2 impaired the quality of stored fruits. Ascorbic acid content decreased with the ripening of fruit (Broughton and Wong, 1979).

Under ordinary conditions, fruits keep well for 7–8 days from picking, unripe fruits can be made to ripen slowly and satisfactorily between 12 and 14 °C and they keep well for about 5 weeks. Ripe fruits can be kept at 2–3 °C and 85–90 per cent relative humidity for 6 weeks and firm fruits at 3 to 5° C for 8 weeks (Singh, 1969 and Singh *et al*, 1963).

15.13 Packaging and Transport

Grading in sapota is largely done by size and shape in our country, particularly in the west coast, and it is arbitrary. The fruits are graded into three categories depending upon the size. They are large, medium and small.

For distant markets, the fruits are packed immediately after harvest in bamboo baskets which are padded with straw, soft grass or dried banana leaves. These baskets have wide or conical mouths. It is advantageous to use standard wooden boxes for packing and transportation over long distance by rail or road.

15.14 Breeding and Varietal Improvement

Hybridisation in sapota

In sapota, there are a large number of varieties differing in several fruit characters such as size, texture of flesh, sweetness and seed number. Hybridisation is one of the means of effecting improvement in this fruit plant so that

desirable traits now found dispersed in different varieties may be combined in one. Preliminary work on hybridisation in sapota was attempted at the then Agricultural College and Research Institute, Coimbatore (Sambamurthi and Ramalingam, 1954). Similar attempts were also made in other parts of the country. At Coimbatore, two commercial parents to combine large size of fruits and superior taste were selected, and they were Cricket Ball and Oval. The seedlings of these crosses were planted in 1954, and they fruited in four years after planting. The fruits are oval and large-sized with an average weight of 125 gm. The flesh is granular and reddish brown in colour, very sweet taste with total soluble solids of 18 per cent. The vegetative and floral characters of the hybrid resemble the parental forms. The seeds are slightly longer than those of both the parents with a conspicuous curvature at the tip (Fazlulla Khan *et al*, 1965).

Similar attempts have also been made at the Agricultural College, Dharwar, Karnataka with four varieties of sapota, namely Kalipatti, Cricket Ball, Calcutta Round and Oval. The fruit size was large when the pollen source was Oval, Kalipatti, Calcutta Round and Cricket Ball. Cricket Ball had the largest fruits and the Oval the smallest. The fruit shape of the self-pollinated fruits was oval and the cross-pollinated fruits roundish (Farooqi and Rao, 1976a). The seedlings of these different crossings have been planted. In another study by the same workers (1976b) on fruit-set through intra and intervarietal pollination in four varieties, open pollination, self-pollination and intervarietal cross-pollination were attempted. In the case of self-pollination, the flower buds were bagged before anthesis or emasculated flowers pollinated with pollen either of the same tree or from a different tree of the same variety. In the case of open pollination the percentage of fruit set ranged between 1 and 24 and 0 to 6 per cent in flowers that were bagged. When the flowers were pollinated with pollen of the same tree, fruit-set was 10 to 27 per cent and it was 3 to 12 per cent when flowers were pollinated from a different tree. Controlled cross-pollination resulted in the highest fruit-set of 78 per cent, but a wide variability existed among the various combinations and their reciprocals. The different varieties selected for the purpose were Kalipatti, Cricket Ball, Calcutta Round and Oval. The most striking behaviour was in respect of Calcutta Round variety which showed one way incompatibility with Kalipatti.

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Sapota in bearing

Avocado fruit

Avocado in bearing

16

AVOCADO

C. R. Muthukrishnan and J.B.M. Md. Abdul Khader

The avocado is one of the most nutritive among fruits. It is regarded as the most important contribution of the New World to the human diet.

16.1 Composition and Uses

TABLE 1. CHEMICAL COMPOSITION OF AVOCADO FRUIT (per 100 gm of edible portion)

General composition		II. *Minerals* (mg)	
Energy value cal.	245·0	Calcium	10·0
Protein (gm)	1·7	Chlorine	11·0
Fat (gm)	26·4	Copper	0·45
Total Carbohydrate (gm)	5·1	Iron	0·60
Crude fibre (gm)	1·8	Magnesium	35·00
III. *Vitamins* (mg)		Manganese	4·21
Vitamin A as β-Carotene	0·17	Phosphorus	38·00
Ascorbic acid	16·00	Potassium	368·00
Niacin	1·10	Sodium	3·00
Riboflavin	0·13	Sulphur	28·50
Thiamin	0·06		

Source : Madhava Rao and Abdul Khader (1977)

The pulp has a buttery consistency, looks very much like cow's butter and bland in taste with a nutty flavour. The common man in our country accustomed to sweet or acidic fruits has not apparently developed a taste for this fruit and the few who consume it, add sugar to the pulp before eating. It does not have any offensive odour or smell ; in fact it has a pleasant aroma of the interior shell of a tender coconut. After attempting once or twice, people normally get used to

the taste and start relishing it. The pulp may be preserved by freezing, is used as a sandwich filling or spread, and in ice-creams and milk shakes. The fruit has a very high fat content and may cause a slight indigestion if consumed too much, though the fat by itself, unlike animal fat, is harmless. As the sugar content is low it can be recommended as a high energy food for diabetics (Samson, 1980). Avocado oil, which is similar in composition to olive oil, is widely used for the preparation of cosmetics.

16.2 Origin and Distribution

Avocado originated in Central America and the early Spanish explorers recorded its cultivation from Mexico to Peru but it was not in the West Indies at that time. It was introduced into Jamaica in about 1650 and to southern Spain in 1601. It was reported in Zanzibar in 1892. Avocado was first recorded in Florida in 1833 and in California in 1856. In India, it may have been introduced in the south and west coast of India about 50 to 75 years ago from Ceylon. Avocado is now grown in most of the tropical and subtropical countries (Purseglove, 1974).

16.3 Species and Varieties

The avocado (*Persea americana* Mill) belongs to the family Lauraceae which has about 47 genera and 1900 species including two other species of economic importance, viz., *Cinnamomum zeylanicum* (cinnamon) and *C. camphora* (camphor).

Species

In avocado, though the following three ecological races (subspecies) have been recognised, it is the natural inter-racial hybrids of these races, that are of horticultural and commercial importance now :

Mexican race : Characterised by small fruits weighing less than 250 gm and ripening 6 to 8 months after flowering. Fruits have thin smooth skin with a large seed fitting loosely in the central cavity and its oil content is up to 30 per cent, the highest of all the three races. Amongst the three races, this race is the most resistant to cold temperature.

Guatemalan race : This race is native to the highlands of Central America. Fruits are fairly large, weighing up to 600 gm and borne on long stalks. The fruits ripen 9 to 12 months after flowering. Their skin is thick and brittle and often warty. Its seeds, held tightly in the hollow of the fruit, are small. The oil content ranges between 8 and 15 per cent.

West Indian race : This group with medium size fruit is native to the lowlands of Central America. The fruit skin is smooth but leathery and glossy. Fruits are borne on long stalks and require up to 9 months for ripening from the date of flowering. Its seeds are large, fitting loosely in the cavity. The oil content of the fruit is low, ranging between 3 and 10 per cent. This race is the least resistant of the three to cold temperatures.

Varieties

Several varieties perpetuated through vegetative means are under cultivation in the New World. Chandler (1958) as well as Samson (1980) have listed quite a number of them. According to the former more than 700 were tried in the USA during the first half of this century. The following are, however, the more important ones :

Fuerte : This is the most popular variety of avocado. It belongs to group B and is a hybrid of the Mexican and Guatemalan races grown in California. Fruits are pyriform, weigh between 225 and 450 gm with 18 to 26 per cent oil. It is fairly resistant to cold ; better suited to subtropic than tropical climate.

Hass : This group A variety is also grown in California where it matures much earlier than the Fuerte. It originated as a seedling from the Guatemalan race. Fruits are medium sized, roundish and turn purple on ripening. This is also more suitable to subtropical climate.

Lula : It is another of Guatemalan origin with pyriform fruits that weigh around 400 to 700 gm. Its oil content is only 15 per cent, i.e., less than that of Fuerte. This is grown in the tropical climate of Florida in the USA.

Pollock : This variety is of West Indian origin with large fruits that weigh up to 1 kg or more but the oil content is less, ranging between 3 and 5 per cent. This is also grown in Florida.

The varieties that are cultivated in India go by several names such as Purple, Green, Fuerte, Pollock, Peradeniya Purple Hybrid, Trapp, Round and Long. The Purple and Green varieties, according to Gandhi (1956) were introduced into India from Ceylon in 1941. His descriptions of the two are as follows :

Purple : This variety belongs to the West Indian race. The fruit is pear-shaped, about 12 to 15 cm long and 6-9 cm broad, with a long neck and about 250 gm in weight. The skin is smooth, shining, deep crimson or maroon in colour, pliable and leathery in texture. It can easily be removed from the pulp. The seed is set loose in the cavity which extends into the neck of the fruit. The flesh is 2 cm thick, firm, smooth and fine in texture, deep yellow, changing to yellowish-green close to the skin, and with a rich and nutty flavour.

Green : The Green avocado belongs to the Guatemalan race. The fruit is large, oval, 250-400 gm in weight. The surface is slightly rough and yellowish-green in colour, the skin being thin but brittle. The seed is large, roundish and

sits tight in the cavity. The neck is solid. The flesh is 2–2·5 cm thick, soft, greenish-yellow, changing to green close to the skin and has a mild nutty flavour.

In summing up the varietal situation in avocado, Samson (1980) concludes that no single variety or group of varieties can be recommended for any location without further investigation and that years, perhaps decades of research will be required. If a plantation is to be raised in a new area, the varieties selected should belong to both groups A and B and their bloom must overlap. The proportion can be 1 : 1 or 2 : 1, with Hass, even 4 : 1. Schroeder (1958) was of the opinion that for testing in a new area, it would always be better to introduce and test avocado seedlings of standard varieties, rather than their clones, as the latter provide only a very little range of variability, while the former being more variable and vigorous would form the best material under such conditions. In a study carried out with this objective at the Tamil Nadu Agricultural University, Coimbatore, Madhava Rao and Abdul Khader (1978a) noted that the quality and yield performance of seedling progenies, in general to be very highly satisfactory. Out of five trees studied, one did not flower, another had poor growth and the rest yielded very well. The observations recorded by them are presented in Table 2.

TABLE 2. FRUITING CHARACTERS OBSERVED IN THREE AVOCADO SEEDLING PROGENIES

Tree *Characters*	I	II	III
Month of peak flowering	December and January	January	January
Month of peak harvest	July	August	August
Fruit shape	Oblong ; base tapering and apex rounded	Oblong ; necked ; and apex rounded	Roundish ; base tapering and apex rounded
Yield* per tree (No.)			
1976	137	80	105
1977	346	309	274
Mean fruit weight (gm)	380	263	177
Weight of pulp (gm)	240	161	105
Skin weight (gm)	81	59	38
Seed weight (gm)	59	43	34
TSS per cent	7·2	6·8	7·6
Fat per cent	21·16	—	—
Skin colour			
(a) Before ripening	Paris green	Viridian green	Paris green
(b) After ripening	Chrysanthemum crimson	Agathia green	Chrysanthemum crimson
Pulp colour	Primrose yellow	Mimosa yellow	Primrose yellow

* First two years of bearing.

Gandhi (1956), Chandler (1958) and Biale and Young (1971) recorded that not all avocado varieties changed their skin colour when they ripened. In this study, fruits of trees I and II changed their skin colour uniformly to dark crimson when they were allowed to ripen in closed containers over a bed of paddy straw. A few, especially the large ones developed a very attractive yellowish and pink blotches even while on the tree before attaining maturity. In all the trees, the indication for attainment of maturity was the slight fading of the green colour and reduction in the glossy lustre of the skin. It was reported by Biale and Young (1971) and Purseglove (1968) that avocado fruits could be stored on the tree even after they attained maturity. The former observed that the fruits of Fuerte and Hass could be retained on the tree even after maturity since they did not soften as long as the stem remained healthy. This characteristic feature was not observed in this study at Coimbatore in any of the trees. Almost all the fruits started dropping off from the trees after attaining maturity.

16.4 Soil and Climate

Soil

Avocado can be grown on a wide range of soil types, but they are extremely sensitive to poor drainage and cannot stand waterlogging ; they are intolerant of saline conditions, the optimum pH being 5–7.

Climate

In Mexico and Colombia, in the regions where avocado is grown, the average temperature is ranged between 12·8 to 28·3 °C and the rainfall between 665 to 1475 mm (Samson, 1980). The range of mean maximum and minimum temperatures in the Nilgiri Hills in Tamil Nadu, where avocado is grown are 27·2 to 33·9 °C and 14·9 to 22·2 °C, respectively. Bultrose and Alexander (1978) studied the influence of temperature and day-length on floral initiation in Fuerte avocado and found that flowers formed if temperature was 20 °C or below, but at higher temperature (25 °C or 30 °C) flower formation was inhibited. Time to flowering was accelerated but number of flowers was reduced if the day-length was shortened from 15 to 9 hours.

In general, avocado trees of the West Indian race produce well in tropical climate, but those of the other two fail to flower or set fruits in the tropics. In contrast, the West Indian race sets little or no fruit in subtropical climate. In regions where minimum winter temperatures of −0·5 to 3·5 °C occur, only the Mexican race survives. If proper race and varieties are chosen, avocadoes can thrive and produce well in climatic conditions ranging from true tropical to warmer parts of the temperate zone.

16.5 Area and Production

Avocado is cultivated commercially in California, Florida and Hawaii States of USA, as well as in several South American countries, South Africa and Australia. In India, it is grown in small pockets as scattered trees around Bangalore and in the hill slopes of Tamil Nadu, Kerala and Coorg. According to Samson (1980) the world production of avocado is increasing rapidly. It rose from 688 thousand tonnes in 1961-65 to 1221 thousand tonnes in 1977.

16.6 Propagation

Seed

Samson (1980) reported that the viability period of avocado seed is short (2–3 week), which can be improved by storing the seed in dry peat or sand at 5 °C. Removal of the seed coat before sowing helps to speed up the germination. If there is a shortage of rootstocks, the seed can be split lengthwise into four or even six parts, leaving a piece of the embryo on each.

Vegetative propagation

Cutting

The rooting capability of avocado cuttings varies greatly depending on the races and varieties. The Mexican races are relatively easy-to-root whereas the West Indian races are most difficult. The Guatemalan race is intermediate in rooting ability on cuttings (Reuveni and Raviv, 1976). Cuttings from young seedlings root more readily than from old trees (Chandler, 1958). Leaf survival on cuttings under mist has been found to be essential for rooting to take place ; leafy cuttings root first. The use of bottom heat (constant 26 °C) in the cutting beds plus soaking the basal ends of cuttings in an aqueous solution of IBA greatly improved the rooting of varieties that normally root slowly (Krezdron *et al*, 1976). Foliar spraying of a mixture of NAA (1×10^{-4}M)+ cytokinin (5×10^{-4}M) once a week prevented leaf shedding and improved rooting of cuttings (Reuveni and Raviv, 1976). Similarly, etiolation and use of root-promoting substance (IBA) usually promoted rooting on avocado cuttings (Ernst and Holtzhausen, 1978). Rooted cuttings grow slowly in the early stages, but eventually make satisfactory trees (Frolich, 1966). The difficulty of rooting avocado cuttings was overcome by producing base etiolated cuttings and such cuttings rooted faster and at a higher percentage (Reuveni and Goren, 1983).

Budding and grafting

Avocado should preferably be propagated vegetatively by budding or grafting. Purseglove (1974) reported that in Florida, 2 to 4 month-old rootstock plants are

side (veneer) grafted, while in California somewhat older stock are shield budded. Pennock (1970) in Puerto Rico obtained 95 per cent success with cleft grafting. At the Kallar Fruit Station in Tamil Nadu, layering as well as approach grafting gave up to 75 per cent success, while in West Bengal chip budding was found successful (Madhava Rao and Abdul Khader 1978b).

Rootstock

According to Bergh (1969), the Mexican race provides nearly all of the rootstocks used in California. The Guatemalan race is more sensitive to cold and has also proved more susceptible to high pH chlorosis and to *Verticillium* wilt. Mexican race rootstocks are used generally in Israel and in South Africa, though in Australia they were found unsatisfactory. *Phytophthora* resistant rootstocks are probably the single most pressing problem for the industry as a whole. A number of immune or highly resistant *Persea* species are known, but unfortunately all have proved incompatible for hybridisation and grafting with *P. americana*. A Mexican scion on a rootstock of the same race results in perhaps the most salt-sensitive of all important fruit trees. West Indian stocks are preferred in warmer regions or where salinity is a problem.

16.7 Cultivation

Planting

The normal planting distance for avocado is 6-12 m depending on vigour of the variety and its growth habit ; for the varieties having a spreading type of growth habit (for example, Fuerte) wider spacing is given. If there is any danger of waterlogging, they should be planted on mounds, for avocado cannot withstand waterlogged condition. The transplants are planted with a ball of earth around the roots. As the avocado wood is soft and brittle, and liable to wind damage, windbreaks should be provided.

Weeding and intercropping

Avocado orchard is clean cultivated, but deep cultivation should be avoided because of surface roots. Intercropping with legumes or shallow rooted crops may be done in young orchards. However, the modern practice in california is to plant at 5×5 m (400 trees/ha) and gradually thin to an ultimate spacing of 10×7 m (140 trees/ha) (Storey, 1972). Weeds should be controlled and mulch may be useful in controlling weeds and conserving moisture. Annual weeds may be controlled by herbicides such as monouron and simazine.

Pruning

Avocado trees are pruned sparingly, mainly by heading back the central shoot in upright growing varieties, such as Pollock, to develop a spreading habit. On the other hand, in spreading varieties like Fuerte, branches are thinned and shortened. Old tall trees may be headed back to facilitate harvesting and other orchard operations. Generally, heavy pruning results in excessive vegetative growth and consequently, the yield is reduced.

Irrigation

Irrigation is necessary if there is no rainfall for an extended period. Lahav and Kalmar (1977) in Israel studied the water requirement of avocado and found that 21-day interval is the optimum irrigation frequency, resulting in increased size and oil percentage of fruits and advancing its harvesting date. This is best done by sprinkling ; flooding is not desirable as it promotes root rot.

Manuring and Fertilisation

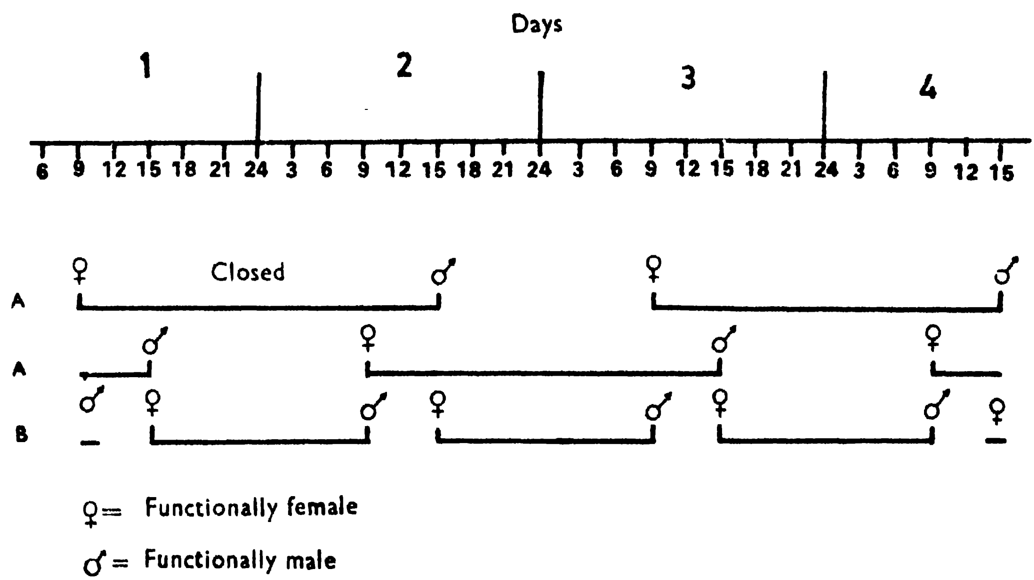
Avocado requires heavy manuring. Of the major nutrients, application of nitrogen was found to be most essential for cultivation of avocado. Azit *et al*, (1975) reported that application of 200 gm nitrogen per plant increased the fruit weight and yield. Bertin *et al*, (1976) suggested to apply 1·6–2·2 per cent N, 0·1-0·3 per cent P, 0·5-2·4 per cent K, 1·0-3·0 per cent Ca and 0·3-0·5 per cent Mg as foliar spray. Healthy Fuerte leaves in California have been found to contain 1·8 per cent N, 0·15 per cent P, 1·5 per cent K, 2·2 per cent Ca and 0·4 per cent S, and 125, 50, 50, 10 and 45 ppm of Fe, Mn, Zn, Cu and B respectively. In general, young avocado trees should get N, P_2O_5 and K_2O in the proportion of 1 : 1 : 1 and older trees in the proportion of 2 : 1 : 2 (Samson, 1980). At a pH above 7 iron dificiency symptoms appear which may be corrected by applying chelated iron at the rate of 35 gm/tree (de Geus, 1973).

16.8 Flowering and Floral Biology

Seedling avocadoes start bearing at 5-6 years, whereas vegetatively propagated plants usually bear earlier, but it is usual to remove the fruits until the plants are 3-4 years old. Avocadoes have a marked tendency to biennial bearing, which is partly controlled by genetic factors. Girdling increases the yield of alternately bearing varieties such as Pollock and Fuerte, but has little effect on regular bearing varieties.

The avocado inflorescence is a compound panicle of raceme with a unique flower behaviour which according to Bergh (1969) can be termed 'protogynous,

diurnally synchronous dichogamy'. While dichogamy indicates that the female and male parts mature at different times; in avocado, it synchronises in such a way that all the open flowers on a tree are female at one time and male at a different time. The synchronisation is diurnal for each tree, flower is functionally male at one part of the day and functionally female during another part of the same day. The dichogamy is also protogynous, the pistil maturing earlier than the stamen. Thus, while the avocado flower is structurally bisexual, it is functionally unisexual. Each flower opens twice and is closed in between ; the first time it functions as a female, the second time as a male. The openings are so timed that self-pollination is unlikely. Based on this unique flower behaviour, avocado varieties can be divided into two groups—A and B (Chandler, 1958). In group A, first opening takes place in the morning, second opening during the afternoon of the following day ; the time lapse is more than 24 hours in group B, first they open in the afternoon then again next morning. Therefore, every morning A-pistils can be fertilised by B-pollen, while during afternoon B-pistils are ready to receive A-pollen. This has been illustrated diagrammatically by Samson (1980). According to him, not



Dichogamous flowering in the Avocado (Samson, 1980)

all varieties or seedling trees follow this pattern. Furthermore, the rhythm is upset by cold or cloudy weather, so that overlapping occurs. Some varieties, e.g., Hass, are known to fruit well in monoclonal stands. Nevertheless, single tree is often unfruitful and mixed planting of varieties is desirable. Honey bees are the chief pollinating agents. Fruit drop is quite common in avocado. Very cool weather at blossoming time or a dry hot wind may cause many young fruits to drop.

Sometimes avocado fruits develop without embryos. Such fruits are generally cylindrical in shape and smaller than the normal ones. Avocado fruits grow in size by means of continuous all division (Chandler, 1958).

16.9 Pests and Diseases

Pests

Scale insects, mealy bugs and mites are the important insect pests of avocadoes.

Diseases

Avocado fruits are found to be seriously infected with a fruit spot disease caused by *Colletotrichum gloeosporioides.* Infection results in shedding of young fruits. The remaining unshed fruits do not attain normal size and become deformed. In some fruits the infection may be latent. The isolated fungus from the fruit does not infect the leaves, but there is another strain of fungus which causes leaf spot disease (Sohi and Sridhar, 1974). Controlled atmospheric storage of fruits in 2 per cent O_2 and 10 per cent CO_2 at 7·2°C for 3-4 weeks prevent development of *C. gloeosporioides* (Spalding and Reeder, 1975).

Infection of avocado fruits by *Fusarium solani* and *F. sambucinum*, causing accelerated softening of fruits, has been reported by Zauberman and Schiffmann-Nadel (1977). Fuerte varieties are found to be susceptible to anthracnose (*Glomerella cingulata* var. minor) and stem end rot (*Dothiorella aromatica*) from fruit set until harvest. The time of infection varies with seasons and is related to rainfall incidence (Peterson, 1978).

Other diseases of avocadoes are cercospora spot (*Cercospora purpura*) and scab (*Sphaceloma perseae*), which attack the leaves as well as the fruits.

The most serious disease of avocadoes is root rot caused by *Phytophthora cinnamomi* which may kill the tree. Root rot is accentuated by poorly drained soils. Ridomil (metalaxyl) mixed with the soil before planting (@ 1 gm a.i./10 kg soil) or applied as a drench to the soil surface around established plants (1 gm a.i./10 litre), controls root rot for at least 4 months after treatment. Two applications of Ridomil applied at a rate of 5 gm a.i./m^2 as a soil drench beneath the canopy of 7 year-old trees affected by root rot, control *P. cinnamomi* without affecting its biological antagonists and permit the trees to recover over a period of 12 months (Allen *et al*, 1980).

16.10 Harvesting

Seeded avocado fruits are 8–10 times larger than seedless ones and their cell number and size are also greater (Blumenfield and Gazit, 1974). Fruit size may

be considered as an index for harvest maturity, but in California, avocado fruits are considered mature and ready for harvest only when the seedcoat within the fruit changes from yellowish-white to dark brown. In more tropical areas, fruits mature with less oil content. Varieties of the three horticultural races differ in oil content, the Mexican race having the highest, Guatemalan race intermediate and West Indian race the lowest. The mature fruits can be stored on the tree for several months. The fruits remain hard as long as they stay on the tree, softening only after harvest.

16.11 Yield

Average yield is about 100–500 fruits per tree. However, good orchards in California have been found to give a yield of 6,000 to 12,000 fruit per acre per annum (Purseglove, 1974).

It can be seen from the Table 2 that the yield performance of the trees was highly satisfactory. In Kallar Fruit Station on the solpes of Nilgiri Hills in South India, the average yield reported was only 35 pounds (15·9 kg) per tree (Anon., 1953). Sriram (1958) has furnished varietywise mean yield data for the different varieties grown in that station. The maximum yield reported by him was only 121 fruits recorded by the variety Peradeniya Purple Hybrid. Chandler (1958) stated that most of the varieties in California rarely bear heavy crops, while according to Purseglove (1974) Californian varieties yield 100 to 500 fruits.

16.12 Ripening and Storage

Ripening

Fruits picked from the same tree at the same time are found to differ in ripening times by as much as 10 days (Young, 1979). When recently picked, mature Fuerte avocado fruits are exposed to 10 ppm ethylene for 36–48 hours at 64°F(18°C) all fruits ripen in 3-4 days after removal from ethylene. In another study, it has been found that ripening of fruits has been accelerated when ethylene treatment is given 2 days after harvesting (Adato and Gazit, 1974). At Coimbatore, the fruits were available for harvest in about six months of flowering. In the colder regions of the United States, varieties like Fuerte, Nabal, Hass and Lyon have been reported by Chandler (1958) to require as much as 12 to 18 months for maturing.

Storage

Avocadoes can be kept for about a month in cold storage ; the optimum temperature being 7°C for Fuerte and 4·5°C for Lula and Booth 8. In general,

5·5 to 6·7°C is the temperature-range for cold storage of avocado fruits (Jacobs, 1974). Low temperature injury (0–4 °C) is evident in fruits stored for longer than 3 to 4 weeks depending on varieties (Zauberman *et al*, 1973) ; semi-firm and soft fruits store better at low temperature than firm fruits. Internal discolouration during storage can be reduced by prompt pre-cooling. Irradiation results in excessive flesh browning (Jacobs, 1974). Fruits wrapped in polythene bags and stored at gradually decreasing temperatures (2 days at 17°, 2 days at 14°, 4 days at 12° and then 8 °C) do not soften for 23 days in Fuerte and 46 days in Nabal (Aharoni *et al*, 1968). Hatton *et al*, (1974) reported that avocadoes stored in an atmosphere of 2 per cent O_2 and 10 per cent CO_2 had up to twice the storage life of comparable fruits stored in normal air. Fruits placed in cold storage when climacteric peak was reached showed more susceptibility to low temperature than firm fruits, but they can be kept at 2 °C for 2 weeks (Bosquez *et al*, 1982).

16.13 Breeding and Varietal Improvement

Selection

Most of the named avocado varieties grown throughout the world originated as a chance seedling. An important variety Fuerte, which was first introduced in California, originated from a seedling tree at Mexico. Several varieties are thus found to be originated in Mexico and Central America, which are now grown with popularity in California (Bargh, 1957). The Guatemalan varieties Benik, Itzamna and Nabal were first introduced as budwood (Janick and Moore, 1975). A number of Mexican race selections have been made in Chile, including 'Campeon', 'Cholula' and the 'Peuminas' (Hodgson, 1959). More than a dozen seedling selections in Bangalore, South India had been described by Raman and Balaram (1967). A number of local selections were also made in Jamaica (Davidson, 1967) of which Elgin, Gimball, Huntley proved worthy.

Hybridisation

Phytophthora root rot is considered as a serious problem in avocado cultivation. Extensive attempts to hybridise the avocado with different *Persea* species of sub-genus *Eriodaphne* that are immune to the root rot have failed (Janick and Moore, 1975). According to Zentmyer *et al*, (1967) the Mexican race 'Duke' has some resistance to root rot but crosses with *Persea* species have been unsuccessful ; both graft and cross incompatibility appear between sub-genus *Persea* which includes the avocado and sub-genus *Eriodaphne* which includes all the known immune species.

Mutation breeding

In avocado, spontaneous mutations with regard to leaf size and shape, fruit size and shape or skin surface have been recognised in some sported limbs, but very little has been found to be of horticultural importance. Good yield evidence for genetic yield differences has been obtained only in Fuerte (Hodgson, 1945). Tetraploidy has been induced in the small fruited Mexicola variety (Jackson and Moore, 1975).

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17

CUSTARD APPLE

C. B. S. RAJPUT

Custard apple is considered as one of the delicious fruits meant for table purpose.

17.1 Composition and Uses

In India, the term custard apple is ordinarily applied to *sharifa* or *sitaphal*. In other parts of the world, the term is applied to atleast four other species belonging to the annonaceous group. The custard apple, *Annona squamosa* L. also known as sweet-sop or sugar apple, is almost entirely eaten as a dessert fruit, although the pulp of the fruit may be mixed with milk to form a drink or made into ice-cream. The pulp has a pleasant texture and flavour. It is sweet with a slight acidity.

Custard apple contains 73·3 per cent moisture, 1·6 per cent protein, 0·3 per cent fat, 0·7 per cent mineral matter, 23·9 per cent carbohydrate, 0·2 per cent calcium, 0·04 per cent phosphorus and 1·0 per cent iron. The calorific value of 100 gms of edible matter is 105. The edible protion of the fruit varies from 28 to 55 per cent. The fruit has a sugar percentage varying from 12·4 to 18·15 and the acidity being 0·26 to 0·65 per cent. The variation in the composition is attributed due to differences in the growing conditions and sampling.

Custard apple leaves have got medicinal properties. Oil is extracted from custard apple seeds for making soap and the cake is used as manure.

17.2 Origin and Distribution

Most of the members of the genus *Annona*, including all major fruits are indigenous to America. Historical and philological facts tend to confirm the theory that custard apple is American in origin. It was formerly thought that

custard apple was indigenous to India. The existence of Sanskrit names in the old epics, the paintings and carvings at Ajanta cave strengthened the supposition. According to De Candolle, the fruit is American in origin and was introduced in India by the Portuguese. Mention of the fruit has been made in the Ain-i-Akbari, the biography of Emperor Akbar, which was written 100 years after the discovery of America. According to Dr. Royle, the species has been naturalised in several parts of India.

Custard apple is a common cultivated fruit in India, China, the Philippines and Cuba. Now it is very widely distributed in the tropics and warmer subtropics. The fruit has got commercial importance in Egypt and Central Africa. In India, custard apple is cultivated and also grows wild over a vast area in the South.

17.3 Species and Varieties

Species

The genus *Annona* contains more than fifty species of woody shrubs and trees, all of which produce aggregate fleshy fruits. Of these *Annona squamosa* L. is probably the most popular fruit. The plants referred to *A. squamosa* are woody shrubs or small trees with fairly stout trunks, reaching a height of 5 to 6 m. The branches bear alternate two-ranked lanceolate and accuminate leaves. The flowers are carried singly or in small groups and occupy an extra axillary position. They are greenish-yellow in colour, comprising three fused sepals, six petals, of which the outer whorl of three are about 2·5 cm long and the inner very much reduced and almost scale like. There are numerous stamens made up of fleshy filaments with two longitudinaly splitting pollen sacs on the outer surface and numerous fairly hairy carpels which are quite free from each other in the centre. Each carpel has a single loculus and a single erect ovule arising from the base. The fruit is formed by the up growth of the receptacle and the development of the carpels which fuse together into a fleshy mass of white pulp. In the white pulp, small black seeds are burried. The surface of the fruit is covered by scale like structures and the carpels retain their individuality in custard apple.

Other species in the genus *Annona* providing edible fruits are *A. reticulata* L., *A. muricata* L. and *A. cherimolia*, L. *A. reticulata* is known as bullock's heart or *ramphal*. The fruit is slightly larger than *A. squamosa* and the carpels are fused to form a rind marked with hexagonal areoles. It has the advantage of containing fewer seeds but the pulp is less delicately flavoured. The sugar content is slightly less than the custard apple. It thrives well up to an elevation of about 1300 m above the sea level and is somewhat less resistant to cold than the custard apple.

A. muricata, the sour-sop is a larger fruit than custard apple. The flesh is spinny and has a white fibrous flesh in which the large black seeds are embedded. It is completely tropical in habitat and not suited to most of North India.

Cherimoya, *A. cherimolia*, is one of the best fruits in the *Annona* group. It is not as sweet as custard apple but has a more distinctive flavour. It grows best in cool and dry subtropical regions.

Atemoya is a cross between custard apple and cherimoya. It bears fruits of larger size, good quality and with fewer seeds.

There are no standard varieties in custard apple. Only two distinct groups such as green fruited and red fruited ones are found. There are possibilities of trees bearing large-sized and good quality fruits in each group. One green fruited custard apple tree bearing large-sized fruits exists in the horticultural garden at IARI, New Delhi.

Varieties

Evaluation of *Annona* germ plasm is in progress at Rahuri, Bangalore and Udaipur centres of All India Coordinated Fruit Improvement Project (Anon., 1983). Performance of some of the *Annona* varieties are presented in Table 1 (Anon., 1981).

TABLE 1. PHYSICO-CHEMICAL COMPOSITION OF SOME ANNONA VARIETIES

Varieties	Fruit weight (gm)	Seeds per fruit	TSS 0 Brix	Acidity (percentage)	Reducing sugar (percentage)	Non-reducing sugar (percentage)
Washington 107005	165	28	21	0·22	15·7	2·5
Red Sitaphal	231	54	25	0·21	19·2	2·7
Washington 98787	126	48	24	0·20	20·3	2·1
Mammoth	183	14	23	0·19	16·6	3·5
Barbados	172	70	24	0·21	19·2	3·1
Local graft	225	50	26	0·29	20·3	3·3
Islandar	483	13	29	0·34	22·7	2·1
Bullock's heart	390	32	28	0·36	22·7	2·3
Balanagar	360	43	27	0·24	22·7	2·0
Atemoya	265	34	25	0·28	19·3	3·5
Atemoya chance seedling	219	36	24	0·28	18·9	3·1
British Guinea	181	58	25	0·31	20·3	3·3
Pink's Mammoth	212	16	24	0·24	19·4	3·4

17.4 Soil and Climate

Custard apple is tolerant to any type of soil. It grows well in rocky as well as in sandy soils. In heavy soils also, it grows well provided there is good drainage facility (Oppenheimer, 1947). It is rather a shallow rooted crop.

Being a tropical crop, custard apple prefers a dry climate. It can withstand mild frost but the fruits become hard and do not ripen in cold weather. During the flowering season a dry climate is preferred. Although flowers are produced during the hot dry weather, fruit-set does not occur until the beginning of the rainy season. The plants can flourish under dry conditions and can withstand drought well.

17.5 Area and Production

As per the report of the Indian Council of Agricultural Research, published during 1955, the area under custard apple was 0·1101 million acres. The area must have achieved a manifold increase by this time. Custard apple is grown in vast areas in the states like Andhra Pradesh, Tamil Nadu, Assam and Orissa. In Orissa, the custard apple is commonly grown as a backyard plant but commercial cultivation of the crop under the *in situ* programme in the state is in progress.

17.6 Propagation

Seed

Custard apple is generally grown from seeds. Seedlings are raised in polythene bags filled with soil and are planted in the field when they attain a height of about 20-25 cm during the rainy season. The plants establish themselves during the rainy season and can withstand unfavourable dry weather thereafter. Sometimes seeds are directly put in the field at the onset of the rainy season. Treatment with GA_3 at 500 ppm to scarified seeds of annona resulted in a high percentage of germination (Hayat, 1963).

Vegetative propagation

Vegetative propagation is gaining popularity now-a-days in custard apple, because there is a great deal of variation among the seed grown trees. The fruits are never true to the type and the size gradually reduces. Among the different methods of vegetative propagation, stem cutting, inarching and budding are now used for multiplication of custard apple.

Cutting

It is a difficult-to-root fruit plant, therefore rooting does not occur easily. Under intermittent mist, 90 per cent rooting was observed with NAA at 5,000 ppm, when the shoots were etiolated for 15 days prior to planting (Dhua *et al*, 1982).

Grafting

Inarching seems to be the most successful method of vegetative propagation in custard apple. Side grafting is also practised to get more advantages. Grafting was found superior to budding in percentage of take and splice and whip grafting showed better result (Durate *et al*, 1974). Researches on different types of vegetative propagation and compatibility of different scion and rootstocks are in progress at the Fruit Research Station, Sangareddy, Andhra Pradesh.

17.7 Cultivation

Planting

Planting is done in the rainy season to take advantage of the available rain water. Seedlings or grafts are planted in previously dug, exposed and filled-in pits of the size 60 × 60 × 60 cm at a distance of 5 m. Square system of planting is commonly adopted.

Irrigation

Custard apple does not require irrigation and is able to produce fair crop without irrigation. The trees may bear more fruits if irrigated during the summer. Watering the plant twice a year in heavier soil and 8 times a year on sandy soil was recommended by Ahmed (1936).

Manuring and fertilisation

In each pit, one or two baskets of well rotten farm yard manure or compost is incorporated at the time of pit filling. A fertiliser mixture of 250 gm containing ammonium sulphate, superphosphate and muriate of potash is also mixed with the soil in every pit. The pit should be kept ready atleast one week before planting.

Ahmed (1936) recommended application of N, P and K for cultivation in the sandy soils of Egypt, while Sturrock (1940) observed that custard apple responds well to organic fertiliser. For very light soil, application of 132 to 176 lb (61·6–79·2 Kg) of organic manure per tree supplemented by commercial fertiliser, specially nitrogen proved effective (Oppenheimer, 1947).

In custard apple, nitrogen deficiency was characterised by severely restricted growth of plants with pale green to yellowish leaves. Phosphorus deficiency led to growth reduction and brown necrotic bands appearing at the tips and margins of leaves and K deficiency produced marginal scorching of leaves (Sadhu and Ghosh, 1976). Rao (1974) reported that malnutrition and lack of moisture increase the number of stone fruits which do not ripen properly. Nutritional studies in progress at Rahuri have shown that 250 gm nitrogen and 125 gm each of phosphorus and potassium per tree per year to be the best for growth and yield (Anon., 1981).

Intercropping

Intercropping is advisable with legumes for the first five years. Intercropping also keeps the soil loose and supplies nitrogen for the crop.

Pruning

If left unpruned, the custard apple forms a bush with large number of branches. Pruning is not recommended in custard apple ordinarily. It is only advisable to prune out old and undesirable branches from the tree. Pruning, in order to maintain vigour, can produce fruits of good quality (Stephens, 1936). Budded or grafted plants are trained to a single stem for better production. Pruning in custard apple should not be done until the buds are ready to start growth in the spring.

17.8 Flowering, Pollination and Fruit set

Both seedling and vegetatively propagated plants come into bearing from four to six years. It takes another four to five years to produce average yields. Five-year-old healthy trees yield about 50 fruits each, while older trees bear up to twice the number (Oppenheimer, 1947). Flowering period extends from spring to the end of the rainy season. A medium size tree bears 1000–1500 flowers in a season but only 2 per cent flowers set and bear fruits. Pollination is a major problem in this crop. It has been found that due to the cumulative effects of protogyny, compound and sticky nature of pollen grains, the wind pollination becomes impracticable. There are no insect pollinators for annona. The stigma receptivity also remains for a short period.

During the rainy season, fruit-set takes place. By that time the temperature is lower and the relative humidity is high. Higher percentage of fruit-set by hand pollination has been reported by various workers.

17.9 Pests and Diseases

Virtually, custard apple is free from insect pests and diseases. Cracking of fruits may sometimes occur as a result of differential moisture supply, which can be overcome by regulated irrigation during dry period.

Anthracnose caused by *Glomerella cingulata* is common in Udaipur. Three fortnightly sprays, beginning from the initiation of symptoms, with Benlate (0·05%) was found to be the best, followed by Baycor (0·1%). Dithane M-45 (0·02%), Bavistin (0·05%), Dithane Z-78 (0·2%) also have proved effective to control the disease (Anon., 1981).

17.10 Harvesting

Custard apple starts bearing at the age of four to six years and declines after 12 to 15 years. Harvesting may extend from September to November, depending on the period of flowering. The fruits are harvested in firm condition when the skin between the segments has turned creamy yellow.

17.11 Yield

An average tree yields 100 to 150 fruits per year, bigger and vigorous tree may yield more and each fruit weighs about 120–230 gm. When the yield declines, the fruits have a gritty texture and many prominent bonny seeds. In trials with Balanagar, Barbados seedlings, British Guinea, Local Sitaphal, Red Sitaphal, Washington 107005 and Washington 98787, per plant yield was found to be maximum in British Guinea, followed by Red Sitaphal while in variety Island Gem the fruit weight was maximum but the yield was lowest (Dass *et al*, 1981).

17.12 Ripening and Storage

Ripening

The fruits do not ripen well on the tree and are artificially ripened in straw. If left on the tree, the mature fruits split open and decay, rather than becoming soft and ready to eat. The fruits are generally kept in straw for a few days to become soft. When ripe they are very delicate and must be handled with care.

Storage

Being a perishable fruit, custard apple cannot be stored for a long period, cold storage is not promising for custard apple. The hard fruit becomes chilled at 15·5°C or below, while though the ripe fruit can be kept for six weeks at 4·4°C, the skin becomes brown and unattractive. As a result it loses market value.

Storage studies conducted at Udaipur have shown that custard apple fruits can be easily stored up to 7 days after treatment with 8% wax emulsion in combination with 400 ppm 2, 4-D or 400 ppm 2, 4, 5-T (Anon., 1983).

17.13 Packaging and Transport

In India, custard apple fruits are sold locally due to their perishable nature. But in other countries they are packed and transported to distant markets.

17.14 Breeding and Varietal Improvement

Lack of promising strains in custard apple is a major drawback. There are no standard varieties also. It is worthwhile to collect the available types and study their performance and perpetuate them sexually to evolve distinct varieties. The only interspecific cross between *A. squamosa* and *A. cherimolia* is the popular atemoya. It produces large sized and good quality fruits.

Promising atemoyas and less seedy annona strains should be collected for a sexual propagation and to obtain interspecific crosses. Iman (1953) working at Dacca, East Bengal, produced tetraploids by cochicine treatment, which had larger, thicker, darker green leaves and also flowered earlier.

There are two promising annonaceous fruits known as biriba (*Rollinia deliciosa*) and the pawpaw (*Asimina triloba*). They may be introduced in India to obtain desirable improvement in custard apple.

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A jackfruit tree with fruits

18

JACKFRUIT

H. N. SAMADDAR

The jackfruit is hardly regarded as a commercial fruit crop although it is very popular in the eastern and southern parts of India. It is the largest amongst the edible fruits.

18.1 Composition and Uses

Tender jackfruit appears in the market in spring and continues until summer as a popular vegetable. Since common vegetables are scarce and costly at that time of the year, jackfruit enjoys a high demand and premium price. Ripe fruit has high nutritive value. It is a comparatively cheap fruit and favoured by the poor people when price of staple food is very high. Jackfruit is known as the 'poor man's food' in the eastern and southern parts of India. The fruit contains minerals, vitamin A and C. Some people believe that it causes digestive ailments. The composition of edible portion is detailed in Table 1 (Anon., 1979).

TABLE 1. COMPOSITION OF JACKFRUIT

	(Per 100 gm of edible portion)		
	Tender	Ripe	Seed
Moisture (%)	84	77·2	64·5
Carbohydrate (gm)	9·4	18·9	25·8
Protein (gm)	2·6	1·9	6·6
Fat (gm)	0·3	0·1	0·4
Fibre (gm)	—	1·1	—
Total mineral matter (gm)	0·9	0·8	1·2
Calcium (mg)	50	20	21
Phosphorus (mg)	97	30	28
Iron (mg)	1·5	500	—
Potassium (mg)	246	—	—
Vitamin A (I.U.)	0	540	17
Thiamin (mg)	0·25	30	—
Riboflavin (mg)	0·11	—	—
Vitamin C (mg)	11	—	—
Calorific value	—	84	—

Source : **Extension Bulletin No. 22, IIHR, Bangalore.**

The fruit is not liked by many people due to its characteristic flavour. The seed is also cooked and used in many culinary preparations.

The skin of the fruit and leaves are excellent cattle feed. Jack timber is valuable for making furniture as it is rarely attacked by white ants.

Possible preserves are pickles, dehydrated leather or thin *papad.* Canning is also successful, jack flakes can be bottled and served after mixing with honey and sugar. Nectar can be prepared from the pulp. The rind is rich in pectin. Extract from the rind can be used for making jelly.

The latex from the bark contains resin. Sometimes this is used to plug holes in earthen vats and buckets. Thus the tree is useful in many ways to the mankind.

18.2 Origin and Distribution

Originally a native to India, the jackfruit is now widely cultivated throughout the tropical low land in both the hemispheres (Ochse *et al*, 1981). Wild jackfruit is found in the Western Ghats of India.

It is commonly grown in Burma and Malaysia and to a considerable extent in Brazil. The English Captain Bligh introduced both jackfruit and breadfruit to the West Indies.

18.3 Species and Varieties

Species

The jackfruit *Artocarpus heterophyllus* Lam. is a member of the family Moraceae. It was previously known as *A. integrifolia*. It is a medium-sized tree, 8 to 10 m tall, having a dense irregular globose crown. The sap is milky white. The leaves are dark green, alternate, petioled, ovate-oblong or obovate. Irregular shaped leaves may be seen in young plants.

A. heterophyllus is a tetraploid species with $2n = 56$ (Habib, 1965). Sinha and Sinha (1971) observed that under Kanpur conditions the plants put forth some growth throughout the year but main growth flushes appear twice, once from July to September and again from March to May.

Artocarpus altilis L. is another related species, commonly known as breadfruit. Probably, it was first introduced from its centre of origin in Malayan Archipelago to India by early Dutch voyagers (Narasingha Rao, 1952). It grows in homestead gardens, mainly in Kerala. The male flowers are produced on long catkins. The fruit is 10 to 15 cm in diameter. The leaves are broad, coarse, green and lobed. The tree is attractive for its foliage. The fruits of nonseeded types contain about 28 per cent starch. In Polynesia, it is considered almost as a staple food. In case of seeded types, only the seeds are cooked and used for culinary purposes.

Other important related species are *A. lakoocha* or Monkey Jack, *A. champeden* and *A. hirsuta*. *A. lakoocha* bears very small edible fruits, 5 to 7 cm in diameter. *A. hirsuta* is a semiwild species. *A. champeden* also bears small fruit and has a strong odour like durian.

Varieties

Being cross-pollinated and mostly seed propagated, the jackfruit has innumerable types or forms considering the fruit characteristics. The types differ widely among themselves in density of spikes on the rind, bearing, size, shape, quality and period of maturity. Innumerable variations in sweetness, acidity, flavour and taste are also observed in jackfruit growing areas. Such variations among clones offer scope for improvement of this fruit crop by clonal selection method. Many types available under various local names have originated in this way. 'Gulabi' (rose-scented), 'Champa' (flavour like that of 'champak'), 'Hazari' (bearing large number of fruits) are a few examples. However, distinct varieties are not available in jackfruit. Cultivated types are broadly classed into two groups by consumers, viz.,

(i) *Soft flesh* : When fully ripe, the fruit yields to the thrust of a finger easily. The pulp is very juicy and soft. The taste varies from very sweet, sweet-acid to insipid.

(ii) *Firm flesh* : The rind does not yield to the thrust easily. The pulp is firm and crispy. The taste is variable in degree of sweetness.

Some distinct types are capable of maintaining their individuality even after propagation by seeds (Naik, 1952) :

(i) *Rudrakshki* : It produces roundish fruits of the size of a large pumelo. The rind is smooth, less spiny than the common jackfruit and the perianth is fleshy but the quality is inferior.

(ii) *Singapore or Ceylon jack* : It has been introduced from Ceylon. This is a highly precocious type, producing fruits approximately within $2\frac{1}{2}$ years of planting the seedlings. Size of the fruit is like common jackfruit. Some trees produce light off-season crop between September and December.

Srinivasan (1971) described a variety named locally as 'Muttam Varikha' which produced fruits of average weight of 7·0 kg with 46 cm length and 23 cm width.

18.4 Soil and Climate

Soil

The jackfruit can grow on a wide variety of soil although it prefers a rich, deep alluvial soil. Soil drainage is of utmost importance. Sub-soil drainage

congestion, rise in water table or flood severely damages the trees and may lead to death. Jackfruit trees can be grown on open-textured light soil or lateritic soil provided nutrients are available.

Climate

Warm humid plains are suitable for jackfruit. It flourishes in humid hill slopes also up to an elevation of 1,500 m. Quality of fruits deteriorates in higher altitudes. It also grows well in arid and warmer plains of South India. Cold weather and frost are harmful. But perhaps it is the most cold tolerant among the members of the genus (Ochse *et al*, 1981).

18.5 Area and Production

The estimate of actual area under this crop is not available. It is rarely grown in plantations but preferred very much in homesteads and as a shade tree or as a mixed crop. It occupies a considerable area in coffee gardens and in roadside plantations. The largest area under jackfruits in India is in Assam where the area is about 8,000 hectare. In Bihar, the area is approximately. 4,000 hectare and in South India the trees occupy an area of about 2,000 hectare. In northern India, jackfruit is grown in foothills of the Himalayas. It grows throughout South India up to an altitude of 2,400 metre (Singh, 1969). Jackfruit also flourishes in the Western Ghats.

18.6 Propagation

Seed

The most common method of propagation of jackfruit is by seed. Generally, 4–5 seeds are planted *in situ* so that the tap root can grow undisturbed. However, seedlings can be raised in pots or polybags. After one or two years the seedlings are planted at site.

Germination of seeds deteriorates in storage. Seventy per cent of the seeds germinate up to 15 days after extraction. But, after 30 days' storage, the germination declined to 40 per cent (Anon., 1967). Hayes (1953) opined that larger seeds germinate better. Soaking of seeds in water for 24 hours has been found to improve the germination (Singh, 1969). Sinha and Sinha (1968) obtained 76·7 per cent germination by soaking in 25 ppm NAA for 24 hours as compared to 60 per cent with 50 ppm NAA and 50 per cent under control. Seedling growth was also better when seeds were soaked in 25 ppm NAA. Sanmugavelu (1971) obtained 100 per cent germination by soaking seeds for 48 hours in GA_3

up to 500 ppm compared to 80 per cent under control. Seedling growth was also better. He also noted that IAA, IBA, NAA and CPA were less effective.

Vegetative

A number of vegetative propagation methods have been attempted by different workers. But the plants were not superior to the seedlings although they could reproduce true to the type (Naik, 1952).

Cutting

Mukherjee and Chatterjee (1979) reported 84 per cent success in rooting of cuttings by etiolation and forcing of shoots followed by treatment with 5,000 ppm IBA, and then keeping under a mist. No rooting was obtained without dipping in IBA. Survival of cuttings was 50-70 per cent. Dhua *et al*, (1983) recorded maximum rooting success (90%) from shoots which were etiolated and ringed for 30 days and then treated with IBA at 3,000 ppm in combination with ferulic acid at 2,000 ppm.

Air-layering

Sen and Bose (1959) reported 100 per cent success in rooting of air-layers and a high percentage of survival under West Bengal conditions. Treatment with IBA markedly improved the root formation.

Grafting

Inarching : Experiment on inarching conducted at the Fruit Research Station, Tamil Nadu revealed that by using *A. hirsuta* or Rudrakshi as rootstocks, jackfruit could be inarched with 60 to 70 per cent success (Naik, 1952).

Epicotyl grafting : Epicotyl grafting with mature, plump, terminal scion shoot on germinating jackfruit seedling of about 8 to 10 days by wedge method during April-May gave 50 to 90 per cent success and the successful epicotyl grafts attained saleable size within a year (Gunjate *et al*, 1982).

Budding

Several methods of budding, tried at different research stations have been proved to be successful :

(i) *Forkert budding* : Modified forkert budding was found very successful in Java (Naik, 1949).

(ii) *Chip budding* : Success was 41 per cent by chip budding at the Horticultural Research Station, Krishnagar (Samaddar and Yadav, 1970).

(iii) *Patch budding* : Teaotia *et al*, (1963) reported 100 per cent success by patch budding.

The grafts became ready for planting one or two years after grafting.

18.7 Cultivation

Land preparation

After clearing weeds, the land is to be ploughed and cross ploughed. It is desirable to dig trench and raise a mud-wall around the plot. The plot is then laid out according to spacing. The land should be prepared well so as to grow an inter-crop like summer vegetables or 'kalai'.

Planting

Commonly, the square system is followed for planting. Hexagonal system may be followed in less fertile soils. In fertile soils a spacing up to 12 m × 12 m accomodating 70 plants per hectare will suffice for this fruit crop. On average soil, trees may be planted 11 m apart. Higher density of planting can be practised in lighter and poorer soils. Shorter spacing in fertile soil will lead to crowding of trees.

Planting method

For planting jackfruit, 1 m cube pits are dug at least 10 days before planting. About 30 kg well-rotten farm yard manure and 500 gm superphosphate are mixed with the soil of each pit and the pit is refilled. Approximately, 50 gm BHC (10%) should be applied in the pit to avoid insect attack. *In situ* planting of 3-4 seeds per pit leads to stronger plant. But nursing and raising of a large number of plants in this way is difficult. After planting, the soil is pressed firmly to avoid waterlogging in pits during rainy season. This is important for the fact that jack-fruit cannot withstand waterlogging.

The best time for planting grafts or seedlings is June through August. Prolonged dry weather after planting may lead to the death of plants. The tap root should not be disturbed while planting to avoid damage to plants.

Care of plants

Jackfruit leaves being a favourite feed for goats, the young plants are frequently damaged by stray goats and cattle unless adequately guarded by providing gabions for about two years. Gabions may have to be replaced after a year. Hand watering of young plants during one or two summers is necessary for assured survival and good growth of plants. In colder regions, protection against frost at least during first few years is safe. Cleaning of basins by spading and ploughing of orchards should be followed as a routine measure. Frequent weeding and mulching are necessary to achieve normal plant growth.

Irrigation

The jackfruit is not normally irrigated. The tree is sensitive to drought. Irrigatian during dry periods is considered essential in arid regions for normal growth. In order to economise use of water, ring system may be adopted for irrigation. For young orchards, hand watering is necessary during first 2 to 3 years till the root system has penetrated deep enough. The frequency of irrigation will depend on the soil moisture condition.

Manuring and fertilisation

Experimental evidence on nutritional requirement of jackfruit is not available. If growth and production appear to be marginal, manuring will be desirable. Farm yard manure or compost may be applied according to the growth and age of the tree and condition of the soil. The trees, however, need nutrition for regular and good cropping.

For quick growth of trees, manures and fertilisers may be added twice a year, before and after monsoon. It is advisable to apply 80 kg of farm yard manure per tree per year. In addition, according to the nutrient status of the soil and growth of the trees, chemical fertilisers should be applied for desired results.

The fertilisers and manures should be spread in the basin and thoroughly mixed with soil by spading. The fertilisers should be applied in an area up to the leaf-drip around each tree leaving a portion around the trunk.

Intercropping

The jackfruit requires a long time to occupy fully the land provided during planting for future mature trees. It is desirable that the interspace should not be left unutilised. Suitable crops should be grown every year till the trees reach bearing stage. When the soil moisture is not a limiting factor, vegetable crops like bhindi, brinjal, chilli, tomato, and pulses like kalai, gram, etc., can be conveniently grown. When the trees come into bearing pulses like gram and kalai can be grown as intercrops. These crops will also improve the nitrogen status in the soil.

18.8 Flowering, Floral biology, Pollination, Fruit-set and Fruit growth

Flowering

Irrespective of the method of propagation, the tree starts bearing from the seventh or eighth year after planting. The flowers generally start appearing in December and continue up to March and the fruit ripens in summer. At higher altitude fruit growth may continue up to September. Occasionally, in rare cases, off-season flowering in September-October may be noticed.

The tree is monoecious. Large number of flowers are borne on club shaped rachis. The inflorescence is a spike covered by two spathes. The female spikes are borne on footstalks while the male spikes appear both on the footstalks as well as on the terminal branchlets. Footstalks bearing female spikes are much more vigorous than those carrying only the male or both male and female spikes. Sambamurthi and Ramalingam (1954) noted that footstalks measuring more than 6·5 cm in circumference at the base seemed to produce female spikes only and that the spikes appearing at the beginning and at the end of flowering season were mostly males.

Sex distribution, floral biology and pollination

The distribution of sex on the jackfruit tree is interesting. On a 16-year-old tree about 2,200 spikes appeared of which 96 per cent were males (Samaddar and Yadav, 1982). Sahadevan *et al*, (1950) recorded 3 to 40 per cent female spikes while Srivastava (1961) reported 20 per cent.

The footstalks carrying female spikes appear on the trunk and main branches adventitiously in the central region of the tree. Male spikes appear both in the central and peripheral regions.

Sex of a spike can be easily identified when it is small. The length and diameter of female spike are much more than those of the males. Surface of a young male spike is smooth while in the case of a female flower it is granular.

A single male flower is actually a stamen enclosed in a green leathery tubular perianth. During anthesis, the stamens protrude out of the perianth tube and appear on the surface of the spike. About 4–6 days after opening from the spathes the first stamen appears. In a couple of days the whole surface of the spike is covered with undehisced yellow anthers or ashy grey dehisced ones held on filaments. After dehiscence, the male spike gradually turns black due to the growth of a mould on it and drops down in another week's time. In a study at the Horticultural Research Station, Krishnagar, it was observed that dehiscence mainly took place in the afternoon. The peak period of anthesis was between 2·00 and 3·00 p.m. and of dehiscence between 3·00 and 4·00 p.m. (Samaddar and Yadav, 1892). In a female flower the perianth encloses the ovary and style. Creamy white stigmas protrude out of the surface of the female spike, 4–6 days after opening from the spathes. In another 4–6 days the whole surface looks wooly. The receptivity of the stigma continues for about 36 hours (Sambamurthi and Ramalingam, 1954). Pollination and fertilisation of a spike are complete within 3–6 days after anthesis. The axis of the inflorescence, the ovaries and perianths all grow simultaneously and develop into a multiple fruit, botanically called a sorosis. The pericarp around each seed and the fleshy perianth are edible.

The jackfruit is anemophilous. Under open pollination the fruit-set is about 75 per cent which is improved by hand pollination.

Fruit growth

The fruits develop during spring and summer. The fruits become ready for harvest in June or early July. If the flowers on all sides are not pollinated the fruit does not develop normally. The size is small and the shape may be irregular in less pollinated fruits. Lack of pollination may lead to the drop of the female spikes.

18.9 Pests and Diseases

Pests

Although a number of pests are known to attack jackfruit, the most important are described below :

Shoot and trunk borer : It is often serious in Assam, Uttar Pradesh and Bihar. It bores into the tender shoots and buds. The affected parts should be nipped off and destroyed. Application of Carbaryl, e.g., Sevin 50 per cent at the rate of 4 gm per litre of water by spray in flowering season is advisable.

The brown weevil (*Ochyromera artocarpi*) is also reported to bore into the tender buds and shoots. They may be controlled by destroying fallen fruits and buds and by collecting grubs and adults.

In addition, mealy bug and jack scale are also found to attack jackfruit which can be controlled by use of a suitable contact insecticide.

Diseases

Among important diseases, the following are worth mentioning. However, these diseases are not serious maladies and can be controlled by prunning off affected parts and using Bordeaux paste at the cut ends.

Pink disease, stem rot, male inflorescence rot and soft rot are occasionally noticed. Soft rot caused by *Rhizopus artocarpi* can be controlled by spraying copper fungicide.

18.10 Harvesting

Tender jackfruits are harvested for use as vegetables during early spring and summer until the seeds harden. The fruit matures towards the end of summer in June. Period of fruit development is February to June. Harvesting is done by cutting off the footstalks carrying the fruits.

18.11 Yield

Bearing starts from the seventh to eighth year when a few fruits may develop. The tree reaches its peak bearing stage within fifteen to sixteen years after planting. Yield is not similar every year. Normally, a tree bears a few to about 250 fruits annually at this stage. The weight of fruits varies widely depending on the type. Individual jackfruit may weigh from a few to about 20 kg.

18.12 Ripening and Storage

In most cases ripening is not a problem. The fruit ripens when the maximum temperature reaches during the end of the summer season. In colder regions, the fruit may mature late. Jackfruit is not normally stored in cold storage. A storage life of about 6 weeks is expected when the temperature is 11·1–12·7 °C and humidity between 85 and 90 per cent (Kripal Singh, 1972). The initial quality and stage of maturity at harvest are important factors on which the storage life depends.

18.13 Breeding and Varietal Improvement

The jackfruit is regarded as a minor fruit and it is seldom found in regular plantations. In spite of its high nutritive values, a wide range of preserves and utility of timber and foliage, the tree is a neglected one. The following measures are suggested for improvement of this potential fruit crop :

Selection of clones

The most important means is to exploit the wide variation among different types grown. Trees of outstanding merits are to be selected after a thorough survey in the growing region. The selected trees should bear large number of fruits of small to medium size. Big size of fruits should be avoided. Fruits should contain larger quantities of pulp with smaller seeds and thinner skin. Selected clones should be propagated vegetatively and a mother orchard has to be established for preparing planting materials.

Breeding

Since a wide range of variation is available in every growing region, it is worthwhile to attempt a breeding programme after selecting the desirable parent trees.

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19

BAEL

SUSANTA K. ROY

Bael (*Aegle marmelos* (L.) Corr.) is an important indigenous fruit of India. The importance of bael fruit lies in its curative properties, which make the tree one of the most useful medicinal plants of India.

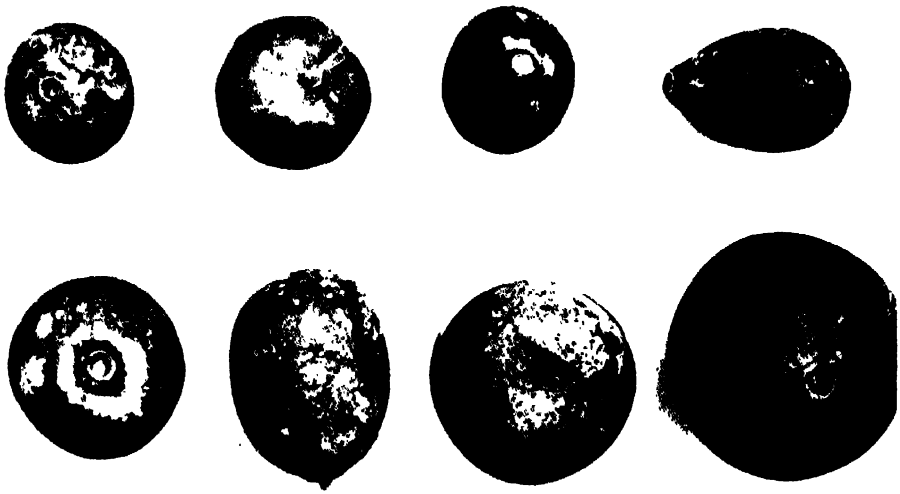
19.1 Composition and Uses

The ripe fruit is laxative and unripe fruit is prescribed for diarrhoea and dysentery. It has a great demand from native systems of medicine such as *Ayurvedic* (Kirtikar *et al*, 1935).

Various chemical constituents, viz., alkaloids, coumarins and steroids have been isolated and identified from different parts of bael tree such as leaves, wood, roots and bark (Chatterjee and Roy, 1957 and 1959 ; Chatterjee and Bhattacharjee, 1959, Shoeb *et al*, 1973). Some studies have also been made on the essential oils of the leaves (Baslas and Deshpande, 1951) and on the physical properties and uses of gums in the preparation of adhesives, water-proofing and oil emulsion coating (Badar-ud-Din, 1950 ; Haksar and Kendurkar, 1961).

The baelfruit is one of the most nutritious fruits. According to Gopalan *et al*, (1971), it contains 61·5 gm water, 1·8 gm protein, 0·39 gm fat, 1·7 gm minerals, 31·8 gm carbohydrates, 55 mg carotene, 0·13 mg thiamine, 1·19 mg riboflavin, 1·1 mg niacin and 8 mg vitamin C per 100 gm of edible portion. No other fruit has such a high content of riboflavin.

Chemical analysis of bael seeds revealed that the seed contained 62 per cent protein (water soluble 2% and 60% insoluble), 32 per cent oil, 3 per cent carbohydrate and 3 per cent ash (Banerjee and Maiti, 1980). Marmelosin is most probably the therapeutically active principle of baelfruit. It has been isolated as a colourless crystalline compound (Dixit and Dutt, 1932).



Bael fruits of different varieties

A bael tree

Bael, because of its hard shell, the mucilaginous texture and numerous seeds, is difficult to eat out of hand and is not popular as a dessert fruit. In the excellent flavour and nutritive and therapeutic values of the baelfruit lies an untapped potentiality for processing (Roy and Singh, 1979a).

19.2 Origin and Distribution

The bael has been known in India from prehistoric times. The leaves of the tree are traditionally used as sacred offering to 'Lord Siva' according to Hindu custom. In the epic ages, such as those of the 'Ramayana' baelfruit was known. Om Prakash (1961) found mention of the bael in Vedas and also in early Buddhist and Jain literatures.

It grows throughout the Indian peninsula as well as in Sri Lanka, Pakistan, Bangladesh, Burma, Thailand and most of the South-East Asian countries.

19.3 Species and Varieties

Species

The genus *Aegle* belonging to the family Rutaceae, consists of 2 or 3 species, and the generic name is of Greek origin. The specific name, ***marmelos*** is a Portuguese one.

The tree is deciduous, 6-8 m in height, with trifoliate aromatic leaves and the branches usually have long straight spines. The bark is shallowly furrowed and corky. The flowers are 2 cm wide, sweet scented and greenish white, the calyx is shallow with 5 short, broad teeth, pubescent outside. There are 5 petals (rarely 4), which are oblong oval, blunt, thick, pale greenish-white, dotted with glands. Stamens are numerous, sometimes coherent in bundles. The ovary is oblong-ovoid slightly tapering, the axis being wide. Cells are many, 8-20, small and arranged in a circle, with numerous ovules in each cell. The fruit is usually globose with the pericarp nearly smooth, greyish-yellow, thick, 2-3 mm hard and filled with soft pulp. Seeds are numerous, compressed and arranged in closely packed tiers in the cells (seed cavity) surrounded by mucilage. The testa is white with woolly hairs. The embryo has large cotyledons (Reuther *et al*, 1967).

Varieties

There are no standard names of varieties of bael. They are generally named after the names of the locality where they are most easily available. Reports on the varieties available so far are mainly from Uttar Pradesh, Bihar and West Bengal (Singh, 1961 ; Teaotia *et al*, 1963 ; Jauhari *et al*. 1969 ; Jauhari and Singh,

1971 ; Mazumdar, 1975). Yield per tree, weight of fruit, number of seeds per fruit, thickness of rind, total soluble solids, total sugars and vitamin C of bael varied from 200 to 400, 1283 to 2818 gm, 74 to 207, 0·16 to 0·28 cm, 28 to 36 per cent, 11·74 to 16·89 per cent, and 13·4 to 22·7 mg/100 gm respectively. Roy and Singh (1978) studied 24 varieties from four different locations in India—Agra, Calcutta, Delhi and Varanasi. Fruits of different varieties were spherical, oblong, cylindrical, pear shaped, flat, etc., weight of the fruit varied from 360 to 1850 gm. The percentages of peel, seeds and fibre of the different varieties of bael were found to vary from 20·54 to 36·11, 0·81 to 5·55 and 1·31 to 4·10 respectively. The maximum edible portion obtained among the varieties studied was 77·25 per cent and minimum 56·12 per cent. The highest moisture content was found to be 62·70 per cent and the lowest 59·37. The percentage of total soluble solids, sugars and mucilages ranged from 31·0 to 35·5, 12·50 to 17·9 and 12.78 to 19·57 respectively. The ranges in acidity, pH, ascorbic acid and phenolics were found to be 0·31 to 0·42 per cent, 5·0 to 5·3, 7·68 to 18·20 mg/100 gm and 3,000 to 17,500 mg/100 gm respectively. The bael contains a substantial amount of phenolics, which contributes to its astringent taste. The organoleptic quality of bael depends upon the balance of mucilage, sugars and total phenolics. A high amount of sugars, particularly non-reducing sugars and low amount of phenolics and mucilage make fruit more palatable.

19.4 Soil and Climate

Bael tree is very hardy and can thrive well even in swampy, alkaline and stony soils having pH range from 5 to 10 (Jauhari and Singh, 1971). According to Davis (1930) bael tree grows even on poor clay soils where other trees fail. Bael trees can be grown up to an altitude of 1,219 m and are not damaged by temperature as low as −7 °C.

19.5 Area and Production

There is no organised orcharding of bael in India. Its cultivation is restricted and it grows mainly wild or in temple gardens. The fruit is available in almost all the states of India, but most abundantly available in Uttar Pradesh, Bihar, West Bengal and Orissa. No data, however, is available regarding its area and production.

19.6 Propagation

Seed

Bael is usually propagated by seeds which are sown in June ; seedlings are transplanted a year later.

Vegetative propagation

Suckers

Bael propagated by seed seldom produces a plant true to type. It can be propagated through root suckers.

Budding

It can also be propagated successfully by budding on 1 or 2 year old root-stock. Experiments were carried out on patch budding, T-budding and chip budding at monthly intervals from July to October and from March to June. Percentage of budtake was higher with patch budding. Budding in the month of June or July gave best results (Singh *et al*, 1976 ; Moti Dhar and Chaturvedi, 1976).

Grafting

Baelfruit can be grafted onto a number of related plants, such as *Aegle fraeglegabonensis* and *Aeglopsis chevalieri* (Reuther *et al*, 1967).

Top working

Old and uneconomic bael tree can be turned into economic and vigorous one by top working. In this method, the tree is headed back 1 to 1½ metres above the ground level during March and new shoots emerge from the stump. A few healthy shoots are retained and desired scions budded on them in the month of June. In this way, inferior and old unproductive bael trees can be transformed into superior and remunerative fruit trees (Jauhari and Singh, 1971).

19.7 Cultivation

There is no recommendation for the preparation of soil and pit or system and methods of planting in bael trees. However, general method adopted in case of citrus plants can be successfully followed. Bael, being a minor fruit, no systematic work has yet been taken up on manuring, fertilisation, irrigation, intercropping, etc.

It was found that many bael trees in southern Florida were suffering from zinc deficiency. Application of small amount of zinc sulphate caused them to make a vigorous new growth with green leaves and favoured the setting and maturing of a good crop of fruit (Reuther *et al*, 1967).

19.8 Fruit Growth and Development

The growth rate of bael has three distinct phases ; the initial slow increase for one month followed by rapid increase for four months and then more or less a stationary phase until the fruits are harvested. From the respiratory studies

baelfruit can be classified as a climacteric fruit (Roy and Singh, 1980). Monthly observation on the morphological changes of bael, as observed by Roy and Singh (1979b) are given below :

Period after fruit-set	*Characteristics of the fruit*
One month (June)	Peel deep green and soft ; no seeds ; the flesh on exposure turns brown very rapidly ; fruit oblong.
Two months (July)	Peel deep green, soft and easily peeled by knife ; flesh light yellow, turns brown on exposure ; small soft seeds and thin mucilage noticed ; fruit oblong.
Three months (August)	Peel deep green, hard, difficult to peel by knife ; flesh light yellow ; seeds soft ; size increased ; mucilage thin ; fruit spherical.
Four months (September)	Peel deep green, very hard, impossible to peel by knife ; flesh light yellow ; seeds a little hard, kernel formation noticed ; mucilage fairly thin, cavity almost full of seeds and mucilage ; fruit spherical.
Five months (October)	Peel green, very hard and woody ; flesh yellow ; seeds hard with hairy growth on surface, kernel prominent ; mucilage fairly thick ; fruit spherical.
Six months (November)	Peel green, very hard and woody ; flesh yellow ; seeds very hard, hairy on surface, kernel prominent ; mucilage thick , fruit spherical.
Seven months (December)	Peel light green, very hard and woody ; flesh deep yellow ; seeds very hard, hairy with full formation of kernel ; mucilage very thick ; fruit spherical.
Eight months (January)	Same as December.
Nine months (February)	Same as January.
Ten months (March)	Peel greenish-yellow ; faint smell of ripeness ; other characteristics as in February.
Eleven months (April)	Peel yellowish-green, hard and brittle ; flesh texture softer ; flavour of ripeness more prominent ; other characteristics as in March.
Fully ripe stage (8 days after harvest)	Peel yellowish ; pronounced ripe baelfruit flavour ; pulp sweet and soft ; fruit detaches easily from the stem end.

Fruit drop is a problem in baelfruit. Pramanik and Bose (1974) tried various growth substances, viz., 2, 4–D, GA_3, 2, 4, 5–T, etc., with different concentrations but could not prevent the fruit drop.

19.9 Pests and Diseases

There is no serious pest on bael.

Diseases

Patel *et al*, (1953) reported that bacterial shot-hole and fruit canker of bael is caused by *Xanthomonas bilvae.* The symptoms on the leaves are characterised by round, water soaked spots (0·5 mm) surrounded by a clear halo. Gradually, the spots increase in size (3 mm to 5 mm) and form brown lesions with saucer like depressions in the centre surrounded by oily, raised margin. The primary localised lesions all over the leaf are always followed by falling-out of the dead tissues leaving circular or slightly irregular perforation or shot-holes. The pathogens also infect the fruit, twigs and thorns.

19.10 Harvesting, Yield, Packaging and Storage

Seedling bael trees require seven to eight years to bear while budded plants start bearing at the age of four to five years. The number and size of the fruit increase with advance in age and size of the tree. Proper care is required for harvesting baelfruit. At the time of harvest, the tree generally gets defoliated and the fruits are completely exposed. The fruit should be picked individually from the tree with a portion of fruiting stalk and should not be allowed to drop. Harvesting by shaking the tree is discouraged as the fruits are likely to develop cracks on impact because of the very brittle peel.

The number of fruits per tree may go up to 200 to 400 at the age of 10 to 15 years. However, a crop of 800 to 1,000 fruits on 40 to 50-year-old seedling tree is not uncommon.

There is no recommended practice for packaging baelfruit. At present, the fruits are packed in gunny bags, baskets and wooden boxes and sometimes they are transported without any packaging.

In order to prevent fungal infection, it is highly desirable that the fruit should not develop any crack during packing, storage, transportation and marketing. The storage life of baelfruit could be increased from two weeks at 30 °C to 12 weeks at 9 °C. Marked physiological breakdown is noticed when storage temperature is below 9 °C (Roy and Singh, 1979c).

19.11 Breeding and Varietal Improvement

There is no systematic work on the breeding and varietal improvement on bael. However, bael provides an excellent scope for improvement of fruit quality by breeding as, in India, different strains are available. If the cultivation of bael is intensified after selecting an ideal variety, this fruit might emerge as a potential fruit for the processing industry.

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20

FIG

M. K. SADHU

Along with date-palm, vinifera grape and olive, the fig was an important food crop for the ancient civilisation of the eastern Mediterranean region and appeared in many songs and legends of historical and mythological background.

20.1 Composition and Uses

Figs are consumed fresh or dried, preserved, candied or canned. Fresh figs are very delicious, wholesome and nutritious and are used as dessert or for making jam. The great bulk of fruit is consumed as dried fruits. When dried and ground it can be used as a substitute for coffee.

Fresh figs generally consist of 84 per cent pulp and 16 per cent skin. The average composition of fig is: calorie 269, protein 4 gm, calcium 200 mg, iron 4 mg, vitamin A 100 IU and thiamin 0·10 mg/100 gm of edible portion (Platt, 1962). Fig is a poor source of vitamin C, but is high in sugar, Ca, Fe and Cu (Mortensen and Bullard, 1968).

The fruit, fresh or dried, is valued for its laxative property. Various medicinal properties are cited by Martinez (1969); its application for boils and other skin infection is reported by Polumin and Huxley (1965) and Font Quer (1973). In some places its latex is used to coagulate milk.

20.2 Origin and Distribution

The edible fig (*Ficus carica* Linn.) is a small deciduous tree which has been under cultivation since antiquity in the eastern Mediterranean region. It is thought to be a native to southern parts of Arabian peninsula, Italy, the Balkan

peninsula and the USSR (Tutin, 1964). It was perhaps first brought into cultivation in the southern parts of the Arabian peninsula by at least 3000 B.C. It later spread into what is now Iraq, Syria and Turkey and into all the Mediterranean countries. During the age of exploration following the discovery of America by Columbus, the fig was taken to most subtropical areas of the western hemisphere.

20.3 Species and Varieties

General morphology

The common fig (*Ficus carica* Linn.) is a small to moderate sized deciduous tree, 6-8 m high with a short twisted trunk, crown with irregular branches; frequently shoots develop at the base of the trunk. The bark is pale grey. Terminal buds are short and stout. Leaves are broad, ovate or nearly orbicular, more or less deeply 3-5 lobed, rough above and pubescent below; long stalked, leaf blade 10-25 cm long, dark green with pronounced venation. Fruits mostly solitary, axillary, green or yellow, brown, purplish or even black depending on variety, more or less pear-shaped with either a velvety or glabrous skin, in certain varieties up to 6 cm in diameter, but normally of modest size.

The edible fig is a multiple fruit. Botanically it is known as syconium which consists of a fleshy hollow receptacle with a narrow aperture at the tip and numerous small flowers lining the inner surface. The true fruits are the tiny drupelets inside the cavity of the fused peduncle.

Types and varieties

Depending upon the nature of flowers and the method of pollination, there are four pomologically distinct classes of fig: (i) *Common fig* or *Adriatic fig*, (ii) *Caprifig*, (iii) *Smyrna fig*, and (iv) *San Pedro fig*.

Common fig: In this type the individual flowers are pistillate and the fruits develop without the stimulation of pollination and fertilisation. Some varieties of this type are Kadota (Dottato), Mission, Adriatic, Brown Turkey, Celeste and Conadria.

Caprifig: It is the most primitive cultivated type with short styled pistillate flowers and functional staminate flowers. Most caprifigs are not edible but are grown because they harbour a small wasp, *Blastophaga psenes*, which is necessary for pollination and setting of fruits.

Smyrna fig: In this type, the fruits do not develop unless the flowers are pollinated with pollen carried from the male flowers of the caprifig by the tiny *Blastophaga* wasp. Calimyrna is the most common and widely cultivated variety of Smyrna type.

San Pedro fig : It is an intermediate type in which the first crop, known as 'breba' crop, is completely parthenocarpic and does not require pollination and fertilisation of flowers, but the second crop develops only if the flowers are pollinated as in the case of Smyrna type. San Pedro, King and Gentile are common varieties of this type.

Of these four types, Smyrna fig is commercially most important and is extensively grown in Europe and USA. It has a superior nutty flavour due to presence of fertile seeds. In India, common fig is mostly grown. It is considered to be a hybrid between imported *F. carica* and indigenous species. A large number of cultivated forms are grown in which the fruits vary in shape, size, colour of skin, colour and flavor of flesh and period of ripening. Some of the varieties grown in India are Black Ischia, Brown Turkey, Turkish White, Kabul and Marseilles. The figs grown in many parts of India are named after locality, but they do not exhibit any special distinction to warrant varietal names. Pune fig is of medium size, bell-shaped and light purple in colour with a rosy flesh. In South India, Pune fig and Marseilles are commonly grown, the latter thriving well in the hilly regions. The fruits of Marseilles are medium-sized, pale green on the rind with a whitish sweet flesh. Condit (1955) gave a good account of 711 varieties of figs and listed 946 synonyms in addition to 98 which he mentioned as having been described by other workers.

20.4 Soil and Climate

Soil

Fig trees grow well on a wide range of soils but do best in deep, non-alkaline clay loams. Alluvial clay loams or medium black soils, which are well-drained but retain enough moisture, are good for fig cultivation. Since fig is a deep rooted plant, it prefers deep soil, although it can be grown in a rather shallow soil.

The fig is one of the most salt and drought tolerant crops (Samson, 1980). It can tolerate a fairly high level of sulphate or chloride salts but are injured when even a small amount of sodium carbonate is present in the soil. The leaves in highly alkaline soils show tip burn and there is considerable leaf fall (Nagpal, 1966). A red loam with a lime substratum and about a metre deep is considered the best for figs in South India (Cheema and others. 1954).

Heavy and poorly drained soils usually produce fruits of inferior quality. Soils having a high lime content produce fruits of better quality suitable for drying.

Climate

The fig is a subtropical fruit. When dormant, mature trees can withstand temperature as low as -12 to $-9{\cdot}5$ °C depending on the variety, but young trees

are not very hardy and may have to be protected during winter. Low temperature of about 1·5–4·5 °C at the time when the trees are not dormant is very much damaging. Similarly, early autumn frost or spring frost when the plant starts sprouting causes considerable damage to the tree. However, in India, the temperature of commercial fig growing areas in southern and western parts of the country seldom goes below 4·5 °C and naturally, the question of low temperature damage does not arise. In northern India, where temperature falls to freezing, the plants remain dormant at that time and normally are not damaged. Figs make good growth when temperatures are above 15·5–21 °C. Although there is no need for chilling to break dormancy, for vigorous shoot growth to take place in the spring, buds of most cultivars require some winter chilling. Continuous growth over major part of the year, complete absence of a well-marked rest period, indistinct flowering and fruiting, prolonged dormancy exhibited by long barren limbs with a cluster of a few laterals at the terminal end are the common features of growth of figs in mild tropical and subtropical areas. The tree usually has a semi-deciduous habit and enters into an inactive phase in the relatively less warm weather, i.e., October to January, and at the end of this, the tree produces only an indistinct amount of flush and flowers. Under such conditions, spraying the trees during December–January with Sandolin A (containing dinitro-ortho-cresol and linseed oil emulsion) results in increased growth activity, early and increased intensity of blossoming and good yield of crops (Shanmugavelu *et al*, 1969).

The climate has a great effect on the characteristics of fig fruits also. The size, shape, colour of the skin and pulp, quality and tendency towards parthenocarpy—all are markedly affected by climate (Condit, 1950). Best quality figs are produced in regions with dry climate, especially at the time of fruit development and maturation. High humidity coupled with low temperature usually results in fruit splitting and lower fruit quality. Fruits formed during March–April under Pune conditions do not ripen because of high humidity and low temperature. Fruits tend to ripen prematurely at temperatures above 38 °C ; such fruits have a tough skin and less pulp. Those fruits exposed to warm breeze in hot areas, though a little sweeter, remain small in size. On the other hand, mild temperature results in large succulent fruits.

20.5 Area and Production

Spain is now the leading fig producing country followed by Italy, Turkey, Greece, Portugal and USA. The world production of fresh figs as given by Schütt (1972) is about 1,255,000 tonnes. According to FAO Production Year Book (1975) the world production totals to about 1,093,000 tonnes.

Although wild figs are growing in India for thousand of years (Hayes, 1957), the common fig is not much grown in spite of the fact that soil and climatic conditions most suitable for fig cultivation are widely found in India. The area under cultivated fig all over the country is nearly 400 hectares and Pune district of Maharashtra is the only area in India where it is cultivated commercially. It is also cultivated in small areas in Bangalore, Srirangapatnam, Bellary and Anantpur in Karnataka. In northern India, it is cultivated in some parts of Uttar Pradesh only. In Punjab, Bihar and West Bengal it is mostly grown scattered in gardens or in home yards.

20.6 Propagation

The fig is readily propagated by hardwood cuttings although all types of budding and grafting as well as air-layering are also successful. Hardwood cuttings, 20-30 cm long and 0·5—0·7 cm thick taken from 1—2-year-old shoots in late summer, are treated with root-promoting substances (IBA), stored in packing material like sawdust at room temperature for about four weeks and then planted when the top buds are just showing. Aminov (1972) reported details of propagation techniques of figs by cuttings. He found the optimum length and diameter of cuttings being 30-40 cm and 1·1-1·5 cm, respectively. Cuttings taken from the base of the shoot and lower part of the crown rooted better than those taken from middle part of the shoot or from upper part of the crown. Rooting was best in cuttings from 3-year-old wood. The optimum soil water for rooting was 20-22 per cent and for shoot growth 16-18 per cent. Application of N at the rate of 30 kg and P at the rate of 22 kg/ha resulted in increased growth of transplants.

Pre-girdling of fig canes, 30 days before taking cuttings, results in quick and increased rooting (Nalawadi and Sulikeri, 1972). In North India, cuttings are made during January-February at the time of pruning, while in South India cuttings are usually made and planted in the rainy season. Sometimes cuttings are directly planted in the field during June-July rather than growing them in the nursery in the first instance. Planting long cuttings (1–1·25 m) directly to the permanent location is also quite common in European countries (Condit, 1947).

Figs can be air-layered successfully and monsoon is the best time for it. One-year-old branches if layered in June can be planted in the field by August-September.

Figs can also be propagated by means of budding or grafting. Success in side grafting has been reported by Naik (1949). Fig is quite susceptible to root-knot nematode and use of resistant rootstocks such as *Ficus glomerata* offers promise where nematode is a problem.

Top working can be done to change an inferior quality variety into better quality variety. For this purpose, shield or patch budding, or cleft or bark grafting can be practised (Nagpal, 1966). NAA sprayed as 1 per cent ethyl ester or sodium salt formulation below the grafts effectively controlled trunk and limb sprouts on top worked fig trees (Nauer and Boswell, 1977).

20.7 Cultivation

Planting

In northern India, rooted cuttings are transplanted in early spring when the plants are still dormant, but in western India, monsoon is the best planting season, while in South India planting can be done any time during the year, but August-September is most preferred.

The spacing ordinarily adopted for fig varies with the size and shape of the variety and the fertility status of the soil. Ordinarily a spacing of 8×8 m is used, but it may be increased to 10 or even 15 m if water is scarce. Close spacing of about 4 m is adopted in Tamil Nadu and Andra Pradesh (Nagpal, 1966) ; in some places of South India the plants are spaced as close as 2 to 3 m apart. It is, however, recommended that varieties ordinarily grown in India should be planted 5 to 7 m apart to obtain the best yield.

Planting is done in 60 cm^3 pits dug at least a month before planting. Pits are usually filled with a mixture of farm-yard-manure or compost and garden soil before the onset of monsoon in southern and western India and in the beginning of spring in northern India. Water is applied immediately after planting.

Pruning and training

Fig trees are pruned annually and trained to a desired height and shape to keep the plant most productive and to facilitate harvesting and other orchard operations. In northern India, trees are headed back to a height of 30 cm or 45 cm, whereas in Pune heading back to about 1-1·5 m is usually done. As the fig tree normally bears 2 crops in a year, the first (known as 'breba') on the wood of previous season and the second crop on new wood of current season, the time and amount of pruning is adjusted according to the growth habit and bearing capacity of the tree. In Pune, light pruning is given just after the crop has been harvested. In Uttar Pradesh severe pruning is given in December, leaving only 3 to 4 buds in shoots of previous year's growth. In Karnataka, the fig plants are headed back every year in January–February to about 2 buds on each shoot of previous season's growth to obtain fruits in July–October. Some growers prefer to prune the tree in October to get fruits in the following summer. In contrast, little or no pruning is done in Tamil Nadu (Naik, 1949).

The main objective of pruning in fig is to induce growth of flower-bearing wood and thereby improve the yield of fruits. In addition, pruning increases the fruit weight in early varieties (Kazas, 1979). Besides pruning, certain other methods such as notching are adopted to stimulate production of laterals on vigorous upright branches. Notching in the form of a slanting cut is given a little above the buds, removing a slice of bark. The depth and width of the notch varies according to the size of the branch. Notching is done in July on at least 8-month-old shoots. It has been found that the lower most 3-4 buds at the basal end of the branch are too dormant to be activated, but the buds on the middle portion of the mature shoot can be successfully activated. It is recommended that only 1 or 2 buds on each shoot be activated by notching (Singh, 1963). A combination of notching and pruning has been found to accelerate more laterals and induce more fruits on the new growth than by pruning or notching alone (Sundararaj *et al*, 1969).

Irrigation

Fig is fairly drought resistant and it is seldom irrigated in many fig growing countries. However, it has been reported from Cairo (UAR) that irrigated plants show greater shoot growth and yield of fruits. Fruits from irrigated trees are heavier by 13·5 to 16 per cent (Ezzat *et al*, 1975). In India also, fig is irrigated during only dry months. Singh and others (1963) suggested irrigation every 1 12 days during summer months. However, care should be taken that at the time of ripening of fruits no irrigation is given, because that may result in the production of insipid fruits. Excessive water in the soil may also cause splitting of fruits.

Manuring and fertilisation

Little is known about cultivation, manuring and irrigation of fig trees in India. Naik (1949) suggested that in South India heavy manuring, frequent irrigation and weeding at least twice a year are necessary for production of good crops. Singh and others (1963) stated that one-year-old trees should receive at least 9 kg farm-yard-manure (FYM) and 170 gm of ammonium sulphate. The quantity of manure is to be increased progressively at the rate of 7 kg of farm-yard-manure and 170 gm ammonium sulphate every year. The usefulness of nitrogen nutrition in fig has been demonstrated by Proebsting and Warner (1954).

20.8 . Flowering, Pollination and Fruit Set

The fig may start bearing a few fruits a year or two after planting, but this crop is not allowed to develop, because the crop may reduce the vegetative growth

of the plant. Usually, steady yield can be obtained from the fifth year onwards. The trees continue to bear good crops for 30–40 years before they begin to decline. The fruits start ripening from March–May in western India and May–July in northern India. In South India, the fig bears twice a year—once in July–September and also in February–May.

The figs commonly grown in India are parthenocarpic in nature and do not need any cross-pollination from wild fig (caprifig), which is a very common practice in other countries. However, fruit setting here is also inhibited under certain conditions. It has been suggested that parthenocarpy is favoured or inhibited in a given type by climatic condition of the place where it is growing. Thus, Pune, Black Ischia and Brown Turkey have been found to be parthenocarpic at Kodur, while Turkish White has failed to set fruits without carpification (Naik, 1949). Likewise, Pune and Black Ischia do not set fruits without caprification in Allahabad (Hayes, 1957). In fact, Smyrna-type figs will never set fruits without pollination from caprifig. Pollen is actually transferred by a small wasp (*Blastophaga psenes*) which overwinters in the pollen producing caprifig (Gerdts and Clark, 1979). The caprifig (with wasp inside) are collected and placed in small bags or wire baskets that are hung in the fruiting Smyrna-type trees. The emerging wasps, covered with pollen, enter the Smyrna fruits and pollinate the long styled pistillate flowers inside (Galil and Neeman, 1977). Thus, for fruit setting of the Smyrna fig caprifig trees as well as the *Blastophaga* wasps are necessary. However, caprification is a cumbersome and expensive process. Considerable success has been achieved by substituting plant growth regulator sprays for caprification. Of the numerous substances tested, IBA, NAA, 2, 4, 5-T and 4–CPA proved effective in inducing early maturing parthenocarpic figs (Crane and Blondeau, 1949, 1950). The parthenocarpic fruits develop to a normal size and have a desirable sugar content, but as they are completely seedless, the baking industries, which use most of the Calimyrna figs produced in the USA, do not want to use it, because they lack the crunchy quality imparted by fig seeds. Subsequently, Crane (1952) found that BOA induces parthenocarpy and the formation of drupelets with hollow, sclerified endocarp, but it is still not acceptable to the industry.

20.9 Fruit growth and Development

Fig fruits show a double sigmoid growth curve—two periods of rapid growth being separated by a period of slow growth (Crane, 1948). It has been known since the third century B.C. that growth and maturation of the fig fruit can be advanced by a few days if a drop of olive oil is applied to the ostiole (eye) during the ten-day period following the time at which all drupelets in the fruit have turned red (Saad *et al*, 1969). This period brackets the transition from stage two

to stage three of fruit growth. The stimulating agent is ethylene, which is produced as a breakdown product of olive oil, especially when the oil is exposed to solar radiation. In fact, it has been found that application of ethylene exogenously in the first growth phase usually retards fruit growth, but accelerates development and ripening when applied in the second growth phase, the fruits ripening within a week after application (Marel and Crane, 1971 ; Puech *et al*, 1976). Ethylene treated fruits not only attain normal size, colour, texture and flavour much earlier than untreated fruits, they also show a higher content of total soluble solids and dry weight (Ben-Yehoshua *et al*, 1970 ; Gerdts and Obenanf, 1972 ; Mougheith and El-Banna, 1974).

20.10 Pests and Diseases

Pests

There are several pests of fig. The major pests are stem-boring beetles (*Batocera rufomaculata, B. rubus*), leaf defoliators (*Adoratus duvauceli, A. versutus*), scale insects (*Aspidiotus lataniae*) and fruit flies (*Dacus dorsalis*). In addition, dried figs are damaged by the fig moth (*Ephestia cuntella*) and the Indian meal moth (*Plodia interpunctella*). Butani (1975) described the major insect pests of fig and their control measures. In addition, fig jassids (*Velucaricae*) and fig midge (*Udumbaria nainienris*) also cause some damage to the crop ; their control measures have been suggested by Awate *et al*. (1976) and Srivastava *et al*, (1977), respectively. Fig leaf roller (*Phycodes minor*) has been reported to occur in Haryana (Lakra and Kharub, 1977) ; excellent control of this pest was obtained with Trichlorphon at 0·05 per cent and Chlorpyrifos at 0·03 per cent.

Figs are also susceptible to root-knot nematodes which can be controlled by fumigation with DD mixture (McKenry *et al*, 1978).

Diseases

Rust caused by *Cerotelium fici* is an important disease of fig in all the fig growing countries including India. Rust affected plants show small, round, brownish to black eruptive lesions on the leaves mostly on the lower surface. The rust causes heavy defoliation of leaves and consequently reduces the yield. It affects all species of *Ficus*. The disease can be controlled by dusting with sulphur or spraying with Zineb (0·15 to 0·20 per cent).

A leaf spot of fig caused by *Cylindrocladium scoparium* has been reported from Uttar Pradesh (Mehta and Bose, 1947). The affected leaves show minute, brown spots, which enlarge into uniform, prominent, reddish-brown lesions with dark brown margins. The lesions mostly coalesce at a later stage into irregular patches. The centre of the lesion is often dropped out. A cobweb-like mycelium spreads

over the lower surface and subsequently becomes powdery. The affected leaves abscise 20-30 days earlier than the healthy ones.

Anthracnose of fig (*Sphaceloma fici-caricae*) is a common disease in certain fig-growing areas of the country. The disease can be controlled by spraying Aureofungin at 40 ppm in soap solution +20 ppm $CuSO_4$ (Wani and Thirumalachar, 1973).

Figs are susceptible to viruses which occur in all the fig-growing countries. In India, a severe fig mosaic has been reported from Himachal Pradesh and Punjab (Nagaich and Vashisth, 1962). The symptoms appear as yellowish-green spots scattered over the lamina. The spots sometimes coalesce to form bigger spots of various shapes and sizes. Occasionally, the leaves develop white mottle and are deformed. The diseased plants do not attain normal size and bear very few fruits. The fig mite, *Aceria ficus* serves as a vector of the virus causing fig mosaic. The virus can infect other species of *Ficus*. *Morus indica* has been reported to be an alternate host of this virus (Vashisth and Nagaich, 1965). The disease can be transmitted by grafting also (Nagaich and Vashisth, 1962).

Vasil'eva (1972) from Crimea (Ukrainian, SSR) listed the principal diseases of fig fruits as *Botrytis cinerea*, *Alternaria fici*, *Fusarium moniliformae* and *Cladosporium sicophilum*. Spraying in late winter with 5 per cent ferrous sulphate or 2 per cent DNOC or in early spring with 3-4 per cent Bordeaux mixture is recommended for the control of the pathogens. In the summer, 0·7 per cent Captain, 0·7 per cent Zineb or 1·0 per cent Ziram should be used. *Alternaria* surface rot of fig fruits can be best controlled by spraying the plants with Chlorothalonil (Bewaji and English, 1976).

Among storage rots, rhizopus rot (*Rhizopus stolonifer*) is quite common. It can be controlled by dipping the fruits in a solution of Aureofungin at 40 ppm in soap solution +20 ppm copper sulphate (Wani and Thirumalachar, 1973).

Disorders

Sunburn

Sunburn is a serious problem of newly planted young trees. The affected parts crack and the bark peels off. Affected trunk or branches may be a centre for infection with fungi. Heavy pruning exposing the trunk and branches is responsible for sunburn. White washing of exposed parts can prevent this malady.

Fruit splitting or cracking

Fruit splitting usually occurs if there is a shower during ripening of fruits. Fruit splitting damages the fruit, making it completely unfit for consumption as it invites infection of rot organisms.

20.11 Harvesting, Yield and Storage

For best flavour, the fruits should not be picked until they are soft and wilt at the neck, hanging down from their own weight. They are then fully mature and

ripe and ready to be eaten. Milky latex exuding from the stem when the fruit is pulled off indicates that the fruit is still immature.

As fresh figs are extremely perishable, fully ripe fruits can not be transported to distant markets, for that purpose it is better to harvest the crop when slightly immature. Ripened fruits are picked either from the tree by twisting the neck at the stem-end or by cutting it or gathered after they drop on the ground. Harvesting may start from the middle of February and continue till June ; fruits are picked every 2 to 4 days. The average yield of figs is 180-360 fruits/tree. A harvest of 12 tonnes/ha can be obtained from a well managed orchard (Samson, 1980).

Fully ripe fresh figs do not keep well ; they can be held only for about a week at 0°C with a 90 per cent humidity. Fully matured figs can be either frozen or dried and still retain their flavour and colour.

There are many fruit products of fig ; dried figs being the most important. Before drying the fruits are subject to sulphur fumigation and then dried in an electric drier at a temperature of 70-72°C.

In another method, fruits are first soaked in boiling salt water for half-a-minute, then dried for a few hours in the sun and for 8 days under shade. At the end of the process the weight is reduced to a little over one-third of the fresh weight (Samson, 1980).

20.12 Breeding and Varietal Improvement

Although fig has been under cultivation for many centuries and is now distributed in many countries of the world, relatively little work has been done for its improvement. Most of the fig varieties cultivated today are selections made by unknown persons in Asia and Europe in the past centuries among wild seedling trees and chance seedlings. Since then these have been maintained clonally by rooted cuttings and in course of time, have acquired names.

The earliest reports on fig breeding are those of Swingle (1908, 1912), Hunt (1911, 1912), Burbank (1914), Rixford (1918, 1926), Noble (1922) and Condit (1928). A project entitled 'Genetics, cytology, morphology and breeding of figs (*Ficus carica*)' is being operated at the University of California since 1922 and as a result of continuous planned breeding work eleven new American varieties have been developed.

The objectives of present-day fig breeding are (i) development of high yielding varieties, (ii) improvement in fruit quality, (iii) elimination of caprification and (iv) transfer of nematode and insect resistance characters of wild fig varieties to high yielding good quality varieties. Storey (1975) described in details the breeding technique being followed in fig.

Trabut (1922) and Condit (1947, 1950) tried interspecific hybridisation involving *F. carica*, *F. palmata* and *F. pseudocarica*. However, the hybrids thus obtained were not of much commercial value. In the Badkhyz area of Turkmenistan (USSR) where *F. afghanistanica* coexists with *F. carica*, spontaneous interspecific hybrids have been found which are intermediate between parents (Petrova and Popov, 1979). New early flowering caprifigs were bred at the Nikita Botanical Garden in Crimea (USSR) using seedlings obtained by intervarietal and interspecific hybridisation. Twelve new caprifigs were selected which are early flowering and produce an abundance of viable pollen (Arendt and Aleksandrova, 1971). Arendt (1974) reviewed the breeding work done in USSR. She obtained best results by interspecific hybridisation using a hardy triploid species referred to as the Afghanistan fig (*F. afghanistanica*) and *F. carica* var. Yellow. The most significant achievement in the history of fig breeding, however, comes from the researches done in California. The fruit characters of eleven new hybrids released and adapted for commercial cultivation in California are given in Table 1.

O'Rourke (1966), Puls, Birchfield and O'Rourke (1967) and Puls and O'Rourke (1967) have reported significant progress in breeding figs for root knot nematode (*Meloidogyne incognita* var. *Acrita*) resistance in Louisiana. A fairly high order of resistance was found in individual seedlings in progenies of the commercially grown varieties Hunt and Celeste.

Diploid apogamy was induced in *F. carica* and *F. afghanistanica* by application of *Lilium candidum* pollen and various physiologically active substances. Adenosine triphosphate stimulated apomictic seed development in *F. carica*, as did naphthylacetamide in *F. afghanistanica* (Romanova, 1979). Numan and Galil (1978) showed that artificial pollination of bagged spring and summer caprifig syconia resulted in seed set and sweet figs were obtained.

Zdruikovskaya-Rikhter (1973) obtained perfect seedlings of *F. afghanistanica* by culturing embryos isolated from seeds in artificial media.

TABLE 1 : FRUIT CHARACTERS OF ELEVEN AMERICAN HYBRID FIG VARIETIES (STOREY, 1975).

Variety	Skin colour	Meat colour	Pulp colour	Shape	Eye	Weight (gm)	Remarks
Conadria	Light yellowish green	White	Light strawberry	Pyriform with thick neck	Very small tight	45-55 avg. 50	Good for drying and for table use, resistant to splitting
DiRedo	Light yellowish green	White	Amber	Globose, short, thick neck	Small tight	50-60 avg. 55	Good for drying, dried figs light in colour, some splitting in adverse weather
Flanders	Light tawny violet stripes and scattered white flecks	White	Light strawberry	Pyriform, long slender neck	Medium, tight	45-54 avg. 50	Excellent fresh fruit, fig for the home garden virtually. Dried figs dark, commercially unattractive
Excel	Light yellow	White	Amber	Ovoid to globose	Medium tight	35-50 avg. 42	Excellent for fresh fruit, canning and drying. Virtually no splitting
Yvonne	Canary yellow	White	Light strawberry	Obovoid	Medium tight	45-55 avg. 50	Matures early, all figs drop in a short time, virtually no splitting
Saleeb	Light green	White	Pale pink	Oblate	Medium tight	48-60 avg. 53	Matures early, yield, well, no splitting
Tena	Greenish	White	Light strawberry	Oblate	Medium tight	45-60 avg. 52	Mid-season, attractive, no splitting
Nardine	Light yellow	White	Amber	Oblate	Medium tight	43-58 avg. 50	Mid-season, attractive, yields well, few split
Deanna	Light yellow	White	Amber	Oblate	Medium tight	45-56 avg. 50	Mid-season, yields well, attractive, no splitting
Gulbun	Light yellow	White	Light pink	Oblate	Medium tight	65-78 avg. 72	Large, mid-season, yields well, few split
Evrem	Light yellow	White	Greenish	Oblate	Medium tight	35-55 avg. 50	Mid-season, attractive, yields well, no splitting

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21

BER

R. YAMDAGNI

The ber (*Zizyphus mauritiana* Lam.) is one of the most ancient and common fruits of India. Being a hardy fruit, it can be grown even on inferior and marginal lands. In view of good returns from ber, its cultivation is becoming increasingly popular in Punjab and other states of North India, specially in Haryana and Rajasthan. In fact, it is an ideal tree fruit for growing in the arid and semi-arid zone.

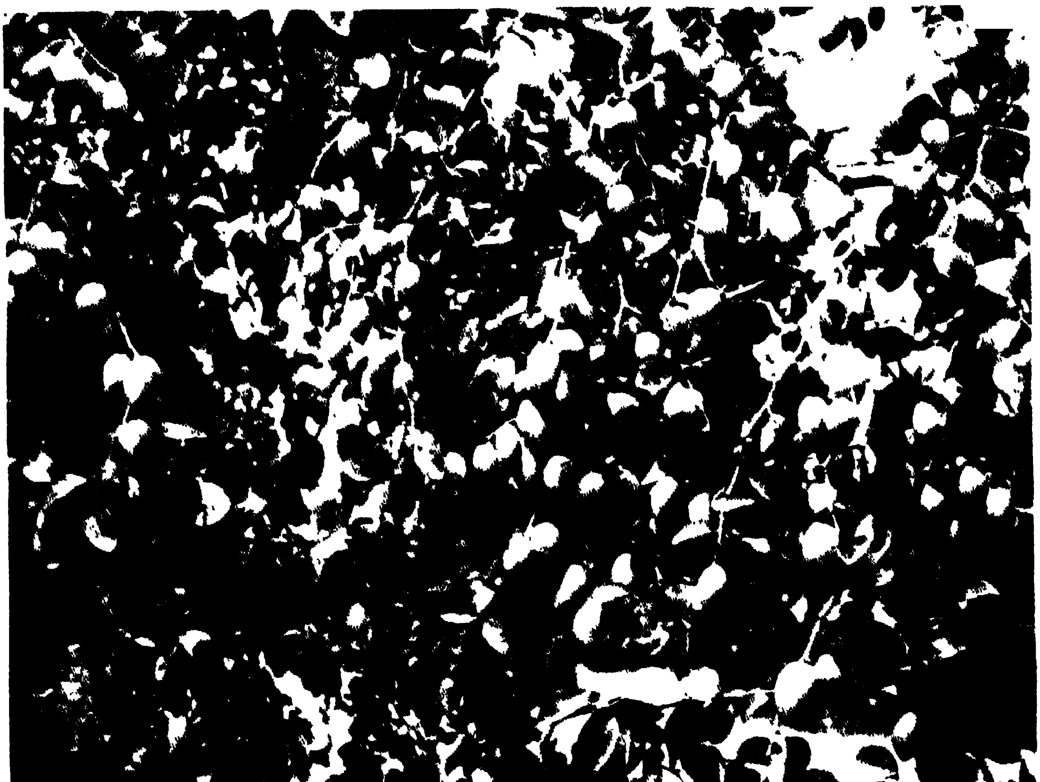
21.1 Composition and Uses

Generally the fruits are eaten fresh, candied, dried, smoked and pickled. Several products like ber butter, ber squash or juice, etc., may also be made. In India *Zizyphus jujuba* Lam is an important host to the lac insect (*Tachardia lacca*) which secrets a resinous substance on the twigs, the raw material from which shellac is prepared. Jujube leaves may be fed to silkworms, the branches and leaves may be lopped for fodder and tanin may be made from the bark.

Though its nutritional and economic importance has not been widely recognised, it has very high potential. The composition of ber fruit is presented in Table 1.

TABLE 1. COMPOSITION OF BER FRUIT

Constituents	Per cent
Moisture	85·9
Protein	0·8
Fat	0·1
Carbohydrates	12·8
Calcium	0·03
Phosphorus	0·03
Iron	0·8
Calorific value per 100 gm	55
Carotene (I.U. vitamin A per 100 gm)	70
Vitamin C (mg per 100 gm)	50 to 150



Ber tree with fruits

Vilaiti　　Banarsi Karaka　　Kaithli

21.2 Origin and Distribution

Jujubes are reported to be indigenous to an area stretching from India to China and Malaysia, though in the tropical parts of this area, *Z. mauritiana* is more common than *Z. jujuba*. The wild species from which cultivated jujubes are believed to be derived, is *Z. sativa* Gaertn, which grows wild and tolerates stony and infertile soils.

In India, jujubes are being cultivated on an estimated 22,000 hectares. These are found growing most widely in the plains of the Punjab, Uttar Pradesh, Haryana, Rajasthan, Madhya Pradesh, Bihar, Maharashtra, Assam, Andhra Pradesh, Tamil Nadu and West Bengal. The fruits are known by several names : ber in Hindi and Punjabi, bor or bogori in Assamese, boroi or kool in Bengali and regu in Telegu. The trees are extremely hardy and thrive, even under the conditions of neglect.

21.3 Species and Varieties

Species

The genus *Zizyphus* belongs to Rhamnaceae or buck-thorn family and includes about 40 species of plants in tropical and subtropical regions of the northern hemisphere. Seven *Zizyphus* species are reported to be native to the United States and Mexico but none of these is of economic importance.

Z. jujuba and *Z. mauritiana* are the two most important species. *Z. jujuba* is the less tropical of these two and is native where temperature ranges from $-6\,^{\circ}C$ to $48\,^{\circ}C$ and rainfall from 125 to over 2,000 mm. *Z. jujuba* is deciduous and has glabrous leaves and is referred as Chinese jujube or chinese date. By contrast *Z. mauritiana* is evergreen, has pubescent leaves and is commercially most important in India. This is referred as ber or Indian jujube. Other important species are :

Z. xylopyrus Willd.	*Z. oenoplia* Mill.
Z. nummularia Burm. F.	*Z. glabrata* Heyne.
Z. fumiculosa Buch-Ham	*Z. oxyphylla* Edgew.
Z. spina christi Willd.	*Z. rugosa* Lam.
Z. vulgaris Lam.	

Varieties

Maximum number of varieties have been reported to be available in China. About 125 varieties are available in India, out of which a few have been classified as early, mid and late. Some of the varieties are known for taste, size, amount

of pulp and higher yields. About 80 varieties are under evaluation at the research stations of Haryana Agricultural University, Hissar and Punjab Agricultural University, Ludhiana. Some of these varieties are described below under early, mid and late groups. Self-incompatibility has been observed in many varieties. It is, therefore, suggested that more than two varieties should be planted together and a single variety for plantation should be avoided. This will also help in regulating the marketing.

Early ripening varieties

Early varieties, such as Gola, Safeda Selected, Seb and Sandhura Narnaul which ripen during February are described below :

Gola : This is one of best varieties and is grown extensively. There are many strains of this variety. It gets good price in the market. The fruits are roundish, golden yellow in colour, average weight around 25·0 gm and length and diameter of the fruits varies from 3·07 to 3·60 cm and 2·45 to 3·25 cm respectively. The pulp of the fruit is soft, semi-juicy, white and sweet. It contains TSS from 16·0–20·0 per cent and the acidity varies from 0·140–0·250 per cent. Gola variety is quite rich in ascorbic acid content (vitamin C) which varies from 70 mg–140 mg per 100 gm of pulp, depending upon the stages of harvesting. A mature tree gives an average yield of 85 kg. However, the yield potential is 125 kg per tree. Since marketability and profits depend upon the size, colour and taste of the fruits, moderate yields should be taken and regulated through annual pruning.

Safeda Selected : This is also a good variety for commercial cultivation. The fruits are roundish, golden yellow with brown tinge, weight of the fruit varies from 20·0-25·0 gm, length and diameter vary from 2·80–3·22 cm and 2·50–3·32 cm respectively. The fruit contains 90·0 per cent pulp which is soft, juicy, sweet and white in colour. It possesses 20·0 per cent total soluble solids, 0·28 per cent acidity and 135 mg ascorbic acid per 100 gm of pulp. The yield per tree varies from 85–125 kg.

Seb : This variety has been selected recently for recommendation to the fruit growers. It is a very good variety from the view-point of polliniser for other varieties. The fruits are slightly roundish, yellowish in colour, weight varies from 15·5–20·5 gm whereas length and diameter from 2·78–3·3 cm and 2·20–3·0 cm respectively. The fruit contains 92·0 per cent pulp, 20·5 per cent total soluble solids, 0·32 per cent acidity and 138·1 mg ascorbic acid per 100 gm of pulp. The yield per tree varies from 90 kg–105 kg.

Sandhura Narnaul : This variety has been selected from Narnaul area in Mahendragarh (Haryana). The fruits are oblong with slight beak and uneven surface, greenish yellow in colour, fruit weight varies from 15·7–18·0 gm, 4·4 cm in length and 2·75 cm in diameter. The fruit is thin-skinned and contains 93·4 per cent pulp which is whitish, very soft, juicy and very sweet. It contains

19·0 per cent total soluble solids, 0·277 per cent acidity and 130·8 mg ascorbic acid per 100 gm of pulp. The yield per tree is about 90 kg.

Mid-season ripening varieties

These include Kaithli, Sanaur 5, Reshmi and Muria Murhara, Desi Alwar and Banarsi Karaka also belong to this group, but due to their average performance and quality under arid and semi-arid conditions, these have not been recommended for commercial plantation. However, Banarsi Karaka in Uttar Pradesh and Desi Alwar in Rajasthan are grown extensively. Self-incompatibility is one of the problems in case of Banarsi Karaka variety. These varieties ripen between first and third week of March. The detailed description is given below :

Kaithli : This is a very popular variety in Haryana and Punjab and as the name indicates, it has been selected from Kaithal area of Kurukshetra (Haryana). The fruits are oblong in shape, weight of the fruit varies from 17·0–22·0 gm, fruit colour brownish-yellow, rind thin but hard, length and diameter is 4·54 and 2·52 cm respectively ; pulp 97·0 per cent which contains 17·4–18·5 per cent total soluble solids, 0·140 per cent acidity and 134·6 mg of ascorbic acid per 100 gm of pulp. A tree can bear from 120–150 kg fruits.

Sanaur 5 : This is also a popular variety grown extensively in Punjab. The fruits are roundish with pointed end, fruit colour greenish-yellow, weight of the fruit varies from 15·50–18·0 gm, length is 4·0 cm and diameter is 3·0 cm, pulp 92·0 per cent, which is soft, creamy white and contains about 20·5 per cent total soluble solids, 0·280 per cent acidity and 161·0 mg ascorbic acid per 100 gm of pulp. A tree can bear 100–125 kg fruits.

Reshmi : This is a good mid-late season variety. The fruits are oblong with rounded tip, weight of the fruit is 13·0 gm, fruit colour greenish-yellow, average length of the fruit is 3·50 cm and diameter 2·5 cm, pulp 94·0 per cent which is whitish, soft and sweet and contains total soluble solids from 17·0–25 0 per cent, acidity from 0·317–0·490 per cent and 115·3 mg ascorbic acid per 100 gm pulp. A tree can bear about 100 kg fruits.

Muria Murhara : This variety has been selected from the germplasm available in Uttar Pradesh and is a good cropper. The fruits are oval in shape and the upper portion is narrow whereas the lower one is broad, weight of the fruit varies from 17·0–24·0 gm, fruit colour is yellow, fruit length 4·61 cm and diameter 3·5 cm. The fruit contains 95·0 per cent pulp which is soft and sweet and contains 19·0 per cent total soluble solids, 0·210 per cent acidity and 183·2 mg ascorbic acid per 100 gm pulp. A tree can yield up to 125 kg fruits.

Late Varieties

These include Umran, Katha Phal, Ponda, Ilaichi and ZG 3. Out of these late varities, only Umran has caught attention of the fruit growers and this variety occupies maximum area in almost all the ber growing areas, particularly

Punjab, Haryana and Gujarat. Other varieties under the group need to be popularised. These varieties ripen between 4th week of March and middle of April. The detailed description is given below :

Umran : It is known for its high yielding characteristic and has potential of giving an yield of over 250 kg per tree. The fruits are oblong and big in size, weight of the fruit varies from 32·5-60·0 gm, fruit colour yellowish with brown tinge, pulp 96·4 per cent which is hard, white, sweet and contains 19·5 per cent TSS, length and diameter being 4·82 and 3·62 cm respectively, acidity varies from 0·28–0·33 per cent and 138·3 mg ascorbic acid per 100 gm of pulp.

Katha Phal : It is known as 'apple' variety in ber because fruits resemble in shape and colour. Fruit is oval, average weight is 16·7 gm, average length and diameter 3·55 and 2·98 cm respectively, the fruit colour is brownish-red at first, which turns into greenish-yellow on ripening, pulp 92·8 per cent, which is soft, white, juicy and has good flavour and taste, average TSS 22·0 per cent and acidity 0·60 per cent and 98·4 mg ascrobic acid per 100 gm pulp. Average yield per tree is 110 kg.

Ponda : It is a variety under late group and can be used in hybridisation programme to impart size and keeping quality. The fruits are oblong and quite big in size, weight of fruit varies from 32·5–55·0 gm, fruit colour is greenish-yellow, fruit length and diameter are 4·27 and 3·37 cm respectively, pulp is hard, white, and contains 15·1 per cent TSS, 0·362 per cent acidity and 167·6 mg ascorbic acid per 100 gm pulp. The yield per tree is 90 kg.

Ilaichi : It is called Ilaichi because the fruits are small and resemble cardamom in shape. It is quite popular in the country because of its peculiar flavour and taste. The fruit is small, average fruit weight is 6·0 gm, the length and diameter being 2·05 and 1·88 cm, pulp slightly hard, white and very sweet and contains 22·5 per cent TSS, 0·315 per cent acidity and 162·7 mg ascorbic acid per 100 gm pulp. The yield per tree is around 115 kg.

Other varieties grown in different states are given below :

Uttar Pradesh : Banarsi Karaka, Lucknow Karaka, Narma, Pewandi, Muria, Jogia, Badshah Pasand, Banarsi, Aliganj, Gola Agra, etc.

Bihar : Nagpuri, Banarsi, Thornless, etc.

Gujarat : Katha, Mehroon, etc.

Andhra Pradesh : Dodhia, Banarsi, etc. Dodhia is not attacked by fruit borer and fly.

West Bengal : Narikeli, Banarsi Prolific, Baruipur, etc.

21.4 Soil and Climate

Soil

The ber plant can be grown successfully in marginal lands having high pH. It can tolerate alkalinity and *kankar* layers (calcium carbonate) at the lower depths. Sandy soils are equally suitable.

Climate

Ber can be grown in different agro-climatic conditions prevaling throughout the country. However, dry and hot climate result in the production of better quality fruits. The physiology of the plant is such that it requires very little water for irrigation as compared to other fruit crops. The plants become dormant during summer and can thus, tolerate adverse weather conditions. The ber trees have tap root system which helps it to draw water from lower strata of the soil. The ber plant can be grown up to an elevation of 1,000 metres. Where other fruits cannot be grown, ber does very well and gives high yields. Excessive heat and cold do not adversely affect the yield and quality of ber. However, excessive moisture or moist conditions are not conducive.

21.5 Propagation

Seed

Seedling trees are commonly found throughout the country. Though they bear very heavy crops, the fruits are small and of poor quality having little commercial value.

Vegetative propagation

Vegetative propagation of improved selected varieties is most important to make ber cultivation economically viable. Only budded plants should be preferred to for commercial plantation. Top working on the existing seedling trees of ber with superior varieties can make these plants remunerative.

Among the various propagation methods, ring budding and shield or T-budding have been quite common and successful. Propagation by cutting and air-layering has also been experimented but with little success. These methods are described below :

Raising of rootstock seedlings

At present seedlings of ber (*Zizyphus mauritiana* Lam.) are used as root-stock throughout the country. Germination of ber seed presents some difficulties on account of the stony nature of the endocarp. It has also been observed that quite a large percentage of seed stones are not viable and require elimination at the time of sowing.

Ber seedlings do not stand transplanting well because they have a long tap root system. It has, therefore, been suggested by several workers that the stock plants be raised at their permanent place in the field. Gokhale (1944) recommended sowing of two seeds of selected wild ber in each pit.

Singh (1957) also considered it best to sow the ber seeds in the field itself at a proper distance and to bud them there when they are ready. However, an alternative method can be recommended which saved much labour. According to this method, fully ripe fruits from wild ber trees were collected during March-April. After removing the edible portion, 8-10 stones were sown in a well prepared 30 cm pot. As soon as the young seedlings put forth four leaves, each was transplanted in separate pot. At the beginning of rainy season these were transplanted in the field. Raising of stock seedlings in pots was also found helpful in sending budded plants to other places (Gokhale, 1944). Experimental results on transplanting of ber rootstock seedlings at two, four, six and eight leaf stages of growth showed that the best success (82 per cent) was achieved when this operation was done at two leaf stage. The rootstocks raised from such seedlings attained buddable size in six weeks after transplanting. The budded plants so raised gave complete establishment in the field (Kanwar *et al*, 1980).

Budding :

Budding is the best and successful method for multiplying ber. However, vegetative propagation of ber is cumbersome and difficult because of its tap root system. Low viability and poor germination in ber seeds may also make the vegetative propagation difficult.

Broadly, there could be two ways of raising orchards with grafted plants, i.e., budding of seedlings *in situ* or transplanting of grafted plants. The budding *in situ* is not popular due to poor success in budding in field. The management of individual budded plant is also difficult. Moreover, ber seedlings to be budded *in situ*, take much longer time to become buddable (Bhambota and Singh, 1971).

In the second method, the seedlings are raised and budded in nursery and then budlings are transplanted in the field. However, the survival rate is low because of root injury during lifting and transportation. The work done at the Haryana Agricultural University, at Hissar has revealed that field-grown seedlings should be preferred to the seedlings raised in alkathene bags. The best time for budding in arid and semi-arid regions is from July to August. The transplanting success, however, is maximum in August with 4-leaf stage budlings. Pareek and Vashistha (1980) recommended the use of soil less ber budlings. Singhrot and Makhija (1979a) found August as the best time for transplanting of budded plants at 4-lea fstage.

The budding may be done either by shield or T or by the ring method. The ring budding may be done during June, when the bark peels off easily and is full of sap. For ring budding, sticks of the scion trees should be of the same

thickness as the stem of the stock which should be of pencil thickness, so that a ring bearing a bud fits in closely when transferred from the scion to the stock. Fresh buds should be used for higher success.

Another popular method of raising ber plant is the shield or T budding, which is better than ring budding, especially when the budsticks have to be obtained from distant places. Budsticks should be chosen from the trees known for quality and yield. Budsticks should be one year-old shoots and the buds on them should be prominent in the leaf axils.

The leaf blade may be removed from the budsticks but the leaf-stalk should remain attached to the buds. The budsticks may be wrapped in moist cloth and stored under moist condition till budding.

Cuttings

Success from root and stem cuttings in Chinese jujube had been reported by Thomas (1924). In Russia also, the Chinese jujube is reported to be propagated through root cuttings.

In India, Jauhari (1960) tried rooting of stem cuttings. Approximately, 20 cm long cuttings carrying 5-7 buds were taken both from ringed and non-ringed branches. The basal ends of these cuttings were dipped in 200 and 400 ppm NAA for 24 hours before they were planted in pots containing coarse sand. Excellent root formation was noticed in three weeks after planting the cuttings. Cuttings taken from non-ringed shoots and treated with 400 ppm NAA also gave 100 per cent rooting. Vigorous root formation was also observed in all the treatments with ringed cuttings, except control. However, Singh (1968) did not obtain any success with unringed cuttings treated with growth regulators and planted in spring (March 1968) and rainy season (August, 1968) at Ludhiana. Kulikav (1972) obtained best rooting (96%), when the cuttings were prepared from the lower part of the shoot and treated with IBA at 50 ppm.

Air-layering

Attempts were made by Jauhari (1960) to propagate ber by air-layering. He treated one to two-year old shoots on 12-15-year old trees with a mixture of 10,000 ppm each of IBA and NAA in lanolin paste. The treated layers were covered with wet sphagnum moss and tied firmly with plastic wrappers. In two weeks after treatment, IBA at 10,000 ppm induced 95 per cent rooting in air-layers (Chatterjee and Rao, 1978).

21.6 Cultivation

Planting

In the past, it was customary to leave the ber trees to themselves without any training or pruning. Such trees attained huge size but production per unit area

was quite low. To get good income ber should be planted 8 metres apart (from row to row and plant to plant) in a square system. Such orchards accommodate greater number of trees per acre, thus fetching higher income. Prior to planting, field should be deeply ploughed and levelled. Pits of 1 m × 1 m × 1 m should be dug at 8 × 8 m distance. The pits should be filled with the original soil mixed with 50 kg FYM, 2 kg superphosphate and 30 gm Aldrex dust (5% Aldrin) or 50 gm BHC 5% dust. The level of newly filled pit should be 10 cm above the ground and then the field is irrigated so that the soil settles down to the ground level. Under rainfed condition the pits should be prepared a fortnight before the onset of rains so that the pits are ready for sowing of seeds or transplanting of grafted plants during the rainy season (August–September).

Transplanting in field can be done in the month of February-March or August-September. However, July-September remains the main season for planting ber plants (Kanwar and Singh, 1981). Singhrot and Makhija (1979b) observed maximum transplanting success during August. They also recommended to transplant budded plants with 6–10 mature leaves and transplanting should be done in the evening of a rainy day. Press the soil firmly after planting and irrigate then immediately. It should be kept in mind that ber plants shed most of its leaves after transplanting and new leaves come out within a month. So irrigation of the plants regularly is recommend for better success of the new ber orchard.

Training

The ber plants should be properly trained during the first 2–3 years to build up a strong framework. After transplanting when new growth starts, fix wooden bamboo sticks for support and straight growth of the plant. Five main primary branches are kept within a height of one to two metres, well spaced in all directions. This will enable the tree to grow in good and balanced shape. The trees start bearing within 2–3 years of planting. In the fourth year, the trees bear normal crop. The fruit is borne in the axils of leaves on young growing shoots of the current year. The training system currently being imparted to the young ber trees is very much similar to the modified leader form. (Dhillon and Dhillon, 1982)

Pruning

Pruning the ber tree is highly desirable, not only during its early years to build a strong framework but also in later years to obtain a profitable crop. The ber fruit is borne in the axil of leaves on the young, growing shoots of the current year. Hence a regular annual pruning is necessary to induce a good healthy growth which will provide maximum fruit bearing area on the tree. Some thinning of the branches is also necessary to avoid crowding. The best time for pruning is the hot, dry season when it sheds leaves and goes to rest. This

happens after the fruits have been harvested. In northern India, the best time of pruning is May. For optimum yield and good quality of fruits, one-fourth of the one-year-old wood should be headed back. All the dry, dead wood and criss-cross branches should be removed with a sharp secateur or the pruning shear. When the proper framework of the tree has been established, pruning should be continued on already established pattern of thinning out and heading back with due consideration to other fundamental aspects of training and pruning. The most important consideration is to maintain a proper balance between the fruiting wood and leaf area. Drastic thinning may rob the trees of valuable carbohydrate reserves for the growth initiation processes in July when active growth starts in ber. Improper pruning and thinning may also lead to hormonal and nutritional imbalance within the tree, and may curtail the productive capacity of the trees considerably. Since the fruit is borne on current season's growth in ber, regular yearly pruning is of utmost necessity to obtain higher yields of good quality fruit (Dhillon and Dhillon, 1982). Singh *et al*, (1973) and Bajwa and Sarowa (1977) recommended light pruning in ber trees to have handsome dividends from ber orchards. Lal and Prasad (1980) concluded that pruning to 90 cm or 120 cm length of limbs should be done for getting higher yield of good quality fruits.

Manuring and fertilisation

Like other fruit trees, ber too needs annual application of manures and fertilisers for good yield. A full grown tree should be given one quintal of well rotten farm yard manure during dormant period (Jawanda and Bal, 1978). In addition, one kg of calcium ammonium nitrate (CAN) per tree should be applied in two split doses, viz., first half during rainy season (July–August) and the other half at the time of fruit set. Additional application of nitrogen up to 500 gm improved fruit set, reduced fruit drop and markedly improved the yield (Yamdagni *et al*, 1980). The following fertiliser schedule seems suitable for optimum production. The quantity of manures and fertiliser would, however, depend upon the fertility status of the soil (Yamdagni, unpublished).

Age of tree (yr.)	FYM (kg)	CAN (kg)	Superphosphate (kg)	Muriate of potash (kg)
1	10	0·500	0·250	0·125
2	15	1·000	0·500	0·250
3	20	1·500	0·750	0·375
4	25	2·000	1·000	0·500
5 and above	30	2·000	1·000	0·500

Half of the nitrogenous fertiliser and full dose of P and K should be applied in the month of July, while remaining dose of CAN should be used during November before irrigation. Ber was grown in sand culture under three levels

each of N, P and K. Deficiency symptoms, growth, flowering and fruiting of plants and nutrient status of stem and leaf as affected by various levels of nutrients were studied by Sadhu *et al*, (1978).

Application of 40–50 kg farm yard manure in July and 0·75 kg ammonium sulphate per tree in October (after fruit set) was suggested by Singh and Singh (1973). Daulta and Chauhan (1982) recommended to apply 50 kg well rotten farm yard manure during dormant period and one kg of nitrogenous fertiliser per tree in two split doses once during rainy season and second at the time of fruit set. If the soil in a particular area has deficiency of any micro-nutrient, that can be applied through foliar spray.

Irrigation

Small plants should be irrigated regularly at 7–10-days interval so that they can establish well and grow normally but full grown trees do not need much irrigation due to its deep tap root system and as they shed leaves during summer months. If possible, irrigate once or twice during development of the fruit for higher yield. First irrigation should be given during November and the other in January. In rainfed areas, bunds should be prepared before rainfall for better utilisation of rain water. The water harvesting technique also helps to increase the bearing capacity in rainfed condition. In this technique, the water of adjoining area is collected around the ber trees by making 5–10 per cent slope of the surrounding areas. Budding *in situ* promotes the growth of tap root which in turn helps to reduce the irrigation requirement in ber.

Intercropping

In ber, intercrops can be grown for 2 to 3 years after planting without any damage to the trees. As the ber trees grow quickly, planting of fruit trees as filler or intercrops is not advisable. However, annual crops like mung, guar and lobia during kharif and gram, berseem, and *methi* can be grown during rabi season. Among fruit plants, phalsa and papaya can be grown as intercrops with ber.

Interculture

The ber orchards should be kept free from weeds and frequent shallow tillage is desirable. Hoeing after irrigation helps to conserve moisture and removal of weeds reduces the loss of moisture and nutrients. Plants of wild *Zizyphus* species should be removed from the orchard because they act as alternate hosts for powdery mildew and fruit fly. Root-suckers grow quickly in ber plantation and they reduce the bearing capacity of the tree. Hence care should be taken for their removal from time to time.

21.7 Flowering, Floral Biology, Pollination and Fruit Set

The flower buds in ber are borne on both mature as well as current season's growth. Teaotia and Chauhan (1964) and Singhota (1973) found that inflorescence in ber is an axillary cyme.

The time of anthesis varied in different varieties. In vars. Sanaur 2, Sanaur 5 and Chhuhara, the anthesis started earlier, i.e., at 6·00 a.m. and continued up to 4·00 p.m. while in ZG 2, Thornless, Kaithli and Umran, anthesis started at 8·00 a.m. and was found to be completed by 4·00 p.m. (Josan *et al*, 1980). Teaotia and Chauhan (1964), Prasad (1964) and Singhota (1973) observed that anthesis occurred at 6·00 a.m. in vars. Pewandi, Banarsi Karaka and Sanaur 5 respectively, while in vars. Thornless, Small Round and Umran, at 12·00 to 1·00 p.m. In most of the varieties dehiscence was found to be started just after anthesis and was completed within 4–5 hours.

In ber, new growth starts in the first fortnight of June in North India and flowering continues for three months from the first week of September to the middle of November, while the fruit set occurs in the month of October (Godara 1980). He further reported that most of ber varieties are self-unfruitful. Ackerman (1961) also showed that many jujube varieties fruit poorly without crosspollination. Studies by Teaotia and Chauhan (1964) and Godara (1980) indicated that in *Z. mauritiana* some varieties are cross-incompatible. Fruits drop immature if they are set without fertilisation or due to embryo abortion at later stage of fruit development. Fruit development completes in 4 months in early ripening varieties whereas the late ripening varieties require 6 months for full growth and ripening.

21.8 Pests and Diseases

Pests

Fruit fly (*Carpomyia vesuviana*) : Among the insect pests, fruit fly causes considerable damage to the ber orchards. The larvae feed inside the fruits and render them unfit for human consumption. To control the pest (i) pick and destroy the infested fruits (ii) spray 500 ml Rogor 30 EC (Dimethoate) in 300 litres of water during February-March, care being taken to stop spraying at least 15 days before fruit harvest.

Hairy catterpillar (*Euproctis fraterna*) : Leaf eating catterpillars feed on leaves during rainy season and may cause huge damage, if not checked. To control these, spray with 750 gm of Sevin 50 per cent (Carbaryl) in 250 litres of water.

Ber beetle : The adults feed on ber leaves. If the attack is severe, the leaf becomes like a sieve. Kapoor and Thakural (1977) recommended spray of 500 ml

Thiodan or one kg Sevin dissolved in 300-400 litres of water to control ber beetle attack.

Lac Insect: It attacks ber shoots. Later on, the affected branches dry up. The attack is marked by whitish red deposition on the affected branches. Kapoor and Thakural (1977) suggested that all the affected branches should be cut back and sprayed with 250 ml Rogor or 85 ml Dimecron, mixed in 250-300 litres of water in the months of April and September.

Diseases

Powdery mildew: Among the diseases of ber, powdery mildew has proved most damaging. Sometimes the attack is so severe that the entire crop is lost either through drop or rendered unmarketable (Jawanda and Bal, 1978).

This disease spreads in October-November and also in the later period of fruit development. White powdery mass starts depositing on fruits. In the beginning, the white spots are small but later on they cover the entire area of the fruits. Sometime, the white powdery mass spreads on flowers and leaves also. These white spots turn brown and heavy fruit drop occurs. Fruit cracking also occurs at the time of maturity of affected fruits. The varieties like Umran, Sandhura Narnaul, Ilaichi, Gola and Kaithli are very susceptible to this disease. This disease is caused by *Oidium* sp. of fungus.

Two sprays of Karathane 0·1 per cent or 0·2 per cent Sulfax at an interval of two weeks, 15 days after fruit set (i.e., in the Ist and 3rd week of November in northern India) are sufficient to control this disease. One spray between July-August is also recommended.

Black leaf spot: This disease spreads in September-October and is characterised by black spots on the lower surface of the leaves. The spots enlarge and cover the entire surface. The upper surface turns brownish in colour and the leaves start falling. This is caused by *Isariopsis* sp. The orchard should be kept clean and sprayed with Dithane Z-78 (0·2%) at an interval of two weeks after the first appearance of the disease.

Cladosporium leaf spot: This disease is not much harmful and can be identified by light brown spots on the upper surface of the leaves. This disease is caused by *Cladosporium* species of fungus. The orchard should be kept clean. Spray Dithane Z–78 (0·2%) in the beginning of this disease at an interval of two weeks to control it. Two sprays are sufficient to control the disease completely.

Fruit rot: Several types of fruit rotting occurs. Initially light-brown spots appear at the apical end of the fruit which later on cover the entire area of the fruit and the affected portion turns dark brown. Sometimes, dark brown rings are formed at the apex. This disease is caused by various species of fungus such as—*Phoma* sp., *Collectotrichum* sp. and *Alternaria* sp.

For its control, spray Dithane Z-78 or Blitox 0·2 per cent at the onset of this disease.

21.9 Harvesting

The peak season for ber fruit harvest in northern India is between February-April. The fruits should be picked at the right stage of maturity, i.e., it should neither be under-ripe nor over-ripe. Grading and sorting should be done to remove under-sized, over-ripe and damaged fruits and the fruits should be sent immediately to the market after packing it properly in bundles or baskets of convenient size.

The immature fruit is green in colour, but at proper ripeness, its colour turns yellowish and finally golden yellow to brownish. Such colour changes during development and ripening of ber fruits has been reported by Bal and Singh (1978). The best time to eat the fresh fruit is before it begins to soften but after 50 per cent or more of the surface has become brown or golden yellow. The best indices for judging the maturity for ber var. Umran are that the specific gravity should be less than 1 with golden yellow colour of the fruits (Bal and Chohan 1981).

21.10 Yield

The yield of ber varies from one to two quintals per tree. Generally, the early ripening varieties bear fruits around one quintal, mid-season one and a half quintals and the late ripening var. Umran gives over two quintals of fruits per tree.

21.11 Ripening and Storage

Ripening

Ripening can be enhanced by using Ethephon. Yamdagni *et al*, (1981) found that 500 ppm Ethephon enhanced ripening by a week in Sandhura Narnaul and Gola. TSS and ascorbic acid contents were higher in the Ethephon treated fruits.

The fresh fruit comes in the market during February-April at a time when there is a slack season for other kinds of fruits. It, therefore, sells readily at remunerative price.

Storage

The properly ripe fruits of Umran ber could be stored for about a week at room temperature (30-35 °C) and for about three weeks in refrigerator (0-4 °C).

Experiments have revealed that the storage life can be extended up to 10 days in Umran and 12 days in Sanaur 2 at room temperature when the fruits were treated with wax emulsion and stored in polythene bags. The fruits remain in good condition up to 30 days in Umran and 40 days in Sanaur 2 in the commercial cold storage (0-3·3 °C), when treated with wax emulsion and stored in polythene bags.

Jawanda *et al*, (1980) reported that the shelf life of the fruits stored in cold storage was better and the fruits of var. Umran remained in good condition up to 30 days and 40 days in Sanaur 2. Bal (1975) reported that ber fruits after 20 days' storage at refrigerated temperature showed little spoilage.

The ber fruit can be utilised profitably for the preparation of several delicious products like candy, dried ber, *murabba*, etc. Ber candy is an excellent product which needs popularisation.

21.12 Breeding and Varietal Improvement

While very little information is available with regard to hybridisation work carried out on ber with the objective of evolving superior varieties, some work has been done on the selection of more promising variety. Ullah and Khan (1954) reported Umran as the best variety from their collection at Lyallpur. A varietal trial with 40 varieties was conducted at the Regional Fruit Research Station, Bahadurgarh from 1955 to 1965 to select high yielding varieties. From this trial Umran, Thornless, Sanaur 2, Seo, Kala gola and ZG 3 were found to be more promising (Anon., 1966). Similarly, from a large collection of about 80 varieties at the experimental orchard of Haryana Agricultural University, Hissar, Sandhura Narnaul, Gola, Kaithli, Muria Murhara, Sanaur 5, Katha Phal and Umran were found suitable for commercial cultivation.

Studies on floral biology and compatibility behaviour of 10 promising ber varieties were conducted at Haryana Agricultural University, Hissar by Godara (1980). He observed variation in the time of anthesis and dehiscence among different varieties. The anthesis took place between 7-15 to 8-00 a.m. in Ilaichi, Katha Phal, Reshmi and Sandhura Narnaul and in the remaining six varieties (Umran, Banarsi Karaka, Kaithli, Muria Murhara, Safeda Selected and Kakrola Gola) it occurred between 12-30 to 1-00 p.m. The number of the days required for the bud development varied between 12·7 and 30·3 days. The pollen germination and tube growth was maximum in 25 per cent sucrose solution. The stigma became receptive 48 hours before anthesis and it continued up to 48 hours. All the ten varieties are self-incompatible. In cross compatibility studies, Ilaichi × Kakrola Gola resulted in highest fruit set, whereas Katha Phal × Safeda Selected and Kaithli × Kakrola Gola showed complete incompatibility. Umran showed best combining ability with other varieties when used as female

or male parent. Out of 43 crosses, where fruit set occurred, the fruits in 18 crosses dropped completly before attaining maturity. The crossability was considerably increased and the premature fruit drop was reduced with colchicine application and EMS treatment improved the crossability but fruit drop was increased due to irradiation. It was also observed that the pollen viability was reduced due to irradiation treatment.

Khoshoo and Singh (1963) reported chromosome number of 35 varieties of Indian jujube. The basic number for this group was 12. They found 33 varieties as tetraploid (2n = 48), one was pentaploid (2n = 60), and 2 were octaploid (2n = 96). Their limited work on the Chinese jujube indicated that most of the varieties may be diploids (2n = 24). It can be concluded from the work of Khoshoo and Singh (1963) and Godara (1980) that higher level of ploidy might be responsible for the self-incompatibility in ber. The self and cross-incompatibility and long juvenile period are the hindrances for a systematic hybridisation programme in this crop.

The work on the improvement of this fruit is in progress at various research centres in India under the All India Coordinated Fruit Improvement Project on Arid Zone Fruits financed by the Indian Council of Agricultural Research.

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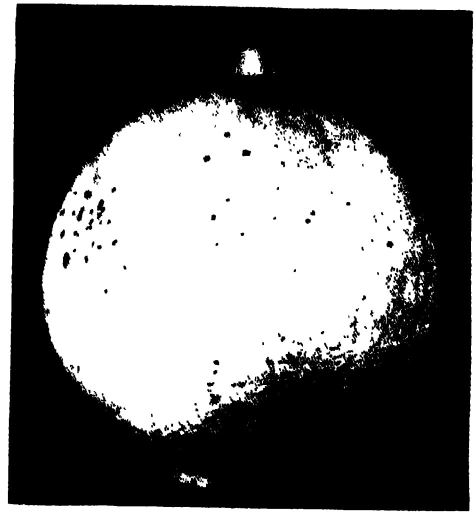

Pomegranate: Muscat

A bunch of pomegranate
var. Ganesh

22

POMEGRANATE

A. V. PATIL and A. R. KARALE,

The pomegranate is commercially grown for its sweet-acidic taste, fruits are mainly used for dessert purposes. The fresh fruit is of exquisite quality, while its processed products such as bottled juice, syrups and jelly are highly appreciated. 'Anar rub' is a product locally prepared from the juice by adding sugar and heating to a thick viscous consistency (total solids 70·75%). It keeps well and is used like tomato sauce or ketchup.

22.1 Composition and Uses

Analysis of the edible portion (68%) of pomegranate from Coonoor gave moisture 78·0%, protein 1·6%, fat 0·1%, fibre 5·1%, carbohydrates 14·5% and mineral matter 0·7%, calcium 10 mg/100 gm, magnesium 12 mg/100 gm, oxalic acid 14 mg/100 gm, phosphorus 70 mg/100 gm, iron 0·3 mg/100 gm. Thiamine 0·06 mg/100 gm, riboflavin 0·10 mg/100 gm, nicotinic acid 0·30 mg/100 gm and vitamin C 14 mg/100 gm.

Tannin occurs in all parts of the tree, particularly in fruit rind (up to 26% in dried rind) stem bark (10 to 25%), root bark (28%) and leaves (11%) which is successfully used alone or mixed with synthetic tannins for tanning leather, from earliest times in the Mediterranean countries and the East. The bark was once much used for production of Morocco leather.

The rind of pomegranate is also the source of a dye which gives yellowish-brown to khaki shades and has been used for dyeing wool and silk. The flowers yield a light red dye said to have been used in India for dyeing cloth.

The bark of the stem and root contain a number of alkaloids belonging to the pyridine group.

22.2 Origin and Distribution

Pomegranate (*Punica granatum* L.), belonging to the family Punicaceae is one of the favourite table fruit of tropical and subtropical regions. The fruit is native of Iran and is extensively cultivated in Mediterranean countries like Spain, Morocco, Egypt, Iran, Afghanistan and Baluchistan. It is also grown to some extent in Burma, China, Japan, USA (California) and India.

As a cultivated crop, the pomegranate is grown to a limited extent in selected locations in almost all states. Maximum area is said to be devoted to it in Maharashtra (880 ha), particularly in Ahmadnagar (400 ha), Solapur (100 ha), Satara (100 ha), Poona (100 ha) and Wardha (100 ha) districts with sprinkling of plantations in other areas. The other states in India, where pomegranate cultivation is important, are Andhra Pradesh, Uttar Pradesh, Tamilnadu, Karnatak and Gujarat.

22.3 Species and Varieties

Species

The genus has two species. (1) *Punica protopunica* (2) *Punica granatum*. *Punica protopunica* is found wild in Socotra Island and *Punica granatum* is cultivated in tropical and subtropical parts. *Punica granatum* has been classified into two subspecies—*Chlorocarpa* and *Porphyrocarpa*. *Chlorocarpa* is found in Transcaucasus region and *Porphyrocarpa* in Central Asia.

Types and Varieties

Several types of pomegranate cultivated in India are distinguished by the shape of the fruit, the colour and thickness of rind, the taste and colour of the seeds. The different types of pomegranate grown in India are summarised below :

Type	Fruit Character
1. Alandi or Vadki	Fruit medium in size ; fleshy testa blood red or deep pink with sweet slightly acidic juice ; seeds very hard.
2. Dholka	Fruit large in size ; rind greenish-white ; fleshy testa pinkish-white or whitish with sweet juice ; seeds soft. Juice is acidic. It is medium cropper.
3. Kabul	Fruit large in size ; rind deep red mixed with pale yellow ; thick, fleshy testa dark red with slightly bitter juice.
4. Kandhari	Fruit large in size ; rind deep red ; fleshy testa blood red or deep pink ; with sweet slightly acidic juice seeds hard.
5. Muskat Red	Fruit small to medium in size ; rind somewhat thick ; fleshy testa with moderately sweet juice, seeds not very hard.
6. Paper Shell	Fruit medium in size ; rind thick ; fleshy testa redish to pink with sweet juice ; seeds soft.

An improved variety known as 'Ganesh' (GBG-1) had been selected from the seedling progeny by Dr. Cheema at Pune which has soft seeds with pinkish flesh and juice with agreeable taste. This variety is a considerable improvement over the local types and bears heavier crops.

Besides those grown for fruits, there are a few ornamental types—a dwarf type and a double-flowered form with red-yellow or white flowers planted in gardens.

22.4 Soil and Climate

Soil

The pomegranate is not very particular about its soil requirement and can be grown on diverse types of soils. The tree gives very good yield in deep loamy or alluvial soil, although it thrives well on comparatively poor soils where other fruits fail to flourish. It can tolerate soils which are limy and slightly alkaline, though it can also be grown in medium or light black soils of at least 60 cm depth.

Climate

The pomegranate is a subtropical fruit tree, growing best in semi-arid climate where cool winter and hot summer prevail. The tree, however, can adapt itself to a wide range of climatic conditions and can be grown all over India. In areas of low winter temperature the tree is deciduous but in tropical and sub-tropical conditions it is evergreen or partially deciduous. The tree requires hot and dry climate during the period of fruit development and ripening. The tree cannot produce sweet fruits unless the temperature is high for a sufficiently long period. The quality of fruit is adversely affected in humid climate. It is a hardy plant and can thrive even under desert conditions. Although it is highly drought-resistant, the pomegranate bears well only under irrigation.

22.5 Propagation

Many pomegranate plantations in India have been raised from seedlings but the seedlings vary too much. The low yields, poor quality of fruits is mainly due to seed propagation. In order to obtain fruits of uniformly high quality, it is necessary that the tree should be propagated vegetatively.

Vegetative propagation is found to be more dependable for preserving and multiplying the selected types. Therefore, common method of propagation is by rooting hard wood cuttings. The cuttings are taken from fully mature wood, about one-year-old. The cuttings are usually taken from suckers which spring

from the base of the main stem and should be 25-30 cm long. Phadnis (1974) indicated that if the cuttings are treated with 200 ppm IAA, not only a majority of the cuttings are induced to root but they also form a profuse root system. The rooting is more effective in rainy season. These are planted in beds during monsoon at a distance of about 40 to 60 cm apart. A year after, the rooted cuttings are lifted out with a ball of earth around their roots and transplanted in the orchard. The pomegranate may also be propagated by air-layering or gootee. Treatment with IBA at 10,000 ppm in lanolin as carrier was found to be the best with regard to the number of roots produced per layer (Suryanarayana and Venkateswara Rao, 1982).

22.6 Cultivation

Planting

The layout is done according to square or hexagonal system. In the generally poor soils of Deccan, the plants are given a spacing of 3.5-5 metres. In a spacing trial at Mahatma Plule Agricultural University, Rahuri, spacings 5×2m, 5×3m, 5×4m, 5×5m were tried and it was observed that as the spacing decreased yield per hectare increased without affecting quality. The spacing 5×2m gave highest yield as compared to normal spacing 5×5m. In lighter but deeper soils the distance is increased to 5×5 m. Pits of 60×60×60 cm are dug at the required distance and filled with about 20 kg of farm yard manure mixed with fine soil. Seedlings/rooted cuttings/air-layers are planted in these pits during monsoon.

Training

Pomegranate plants are allowed to grow in bush form with a number of main shoots arising at ground level. Normally, growers find it convenient to allow 4-5 main stems to develop. It is advisable, however, that the young plants are properly trained to form a single stem with a number of well distributed scaffold limbs. But pomegranate has a tendency to throw out suckers and as such it is rather difficult to train the plant to a single stem. To attain this, all the side shoots should be removed at the time of planting. The main stem should be pinched at a height of about one metre and up to 25-30 cm below cut surface 4-5 branches well distributed on all sides should be allowed to grow to form main limbs on the tree. The desired shape of the tree is formed within 2 to 3 years of planting. The trees trained to single stem do not ordinarily produce many suckers. Trial was laid out at the Agricultural University, Rahuri to see the effect of one stem to 5-stem training. But in the initial period multi-stem training did not give increased yield.

Pruning

Pomegranate does not usually require pruning except for removing the suckers (water sprouts) and giving a shape to the tree. The tree should be allowed to grow on a clean mainstem by pruning the side branches. The fruits are borne terminally on short spurs produced all along the slow growing mature wood. During the period, the fruits are developing on mature wood, the terminals produce new growth flushes that bear the future crop. Cutting back of the terminals would therefore be disastrous and would result in a luxuriant crop of leaves at the expense of fruit. The interior of the plant also becomes devoid of fruits. For securing shapely tree and getting a good crop, a set of new shoots should be a allowed to grow every year on all sides of the tree. The pruning should be confined to a shortening of the past season's growth.

Irrigation

Pomegranate responds well to irrigation. In Gujarat and Maharashtra, the bed or basin system of irrigation is practised. In this, small round basins are made at the base of each tree and these are filled with water. Monsoon showers are supplemented by irrigation during May and June. Copious and regular irrigation is essential during fruiting season, as irregular moisture condition results in cracking of fruits.

Manuring and Fertilisation

Well rotted FYM is usually applied to pomegranate plants at the rate of about 20 kg per tree while planting. After this, about 20 kg of FYM is given to each plant every year at the break of monsoon. Application of small quantity of ammonium sulphate is also recommended.

In case of bearing orchards, the manures or fertilisers have to be applied at the time of bahar treatment. In a manurial trial conducted at Mahatma Phule Agriculture University, Rahuri, dose of 500 gm N, 250 gm P_2O_5 and 250 gm K_2O/plant has been found to be adequate for 4-6 years old bearing tree for economic yields.

Application of 20 kg farm-yard-manure and ash per plant at the beginning of monsoon was suggested by Cheema *et al.* (1954). Phadnis (1974) recommended to apply 50 kg FYM and 3-5 kg oilcake or 1 kg sulphate of ammonia prior to flowering for healthy growth as well as fruiting. Pathak and Pundir (1981) suggested application of N, P and K at 240, 160 and 60 kg respectively per hectare. It was also observed that high dose of N and P caused earliness in flowering and it was delayed in plants receiving low dose of N, P and K.

Intercropping

Since the pomegranate takes about 4 to 5 years to come to good bearing, intercropping is highly desirable. Low growing vegetables, pulses or green manure crops may be grown as intercrop in between young trees till 4 to 5 years of their age.

Bahar or Resting treatment

The treatment consists in withholding of water for about two months in advance of the normal flowering season. After two months, soil is mixed with manure and light irrigations are given. Three or four days later heavier irrigation at normal intervals are followed. The trees readily respond to this treatment by producing fresh growth and blossoms and bear a heavy crop of fruits.

Normally, the pomegranate starts fruiting in about 4 years after planting. According to seasonal changes, there are three flowering seasons in Deccan, viz., June–July (*Mrig bahar*) coinciding with the break of monsoon, February–March (*Ambia bahar*) and September–October (*Hasth bahar*). Although the pomegranate may be induced to bear fruit in any of the seasons, ordinarily, only one *bahar* is taken from a tree and the season of fruiting to be adopted is mainly determined by the market factors and the availability of water.

In the Deccan, *Mrig bahar* is taken where water is scarce during the hot weather and therefore, the flowering is so forced that the maximum requirement of water falls during the rainy season or immediately after the rains when plenty of water is available. For *Mrig bahar* treatment, withholding of irrigation from December to April–May results in sufficient suppression of growth. The land is ploughed up or a shallow hand digging is given in April up to a depth of 10 cm. The trees usually shed their leaves by March and remain in dormant condition up to May. The manure and fertiliser are applied and the first light irrigation is given in the middle of May and thereafter one or two light irrigations may have to be given before the rains set in. The trees start their growth by June with the onset of rains and flowers and fruits are produced. The fruits ripen in October and the harvesting continues up to December. In dry regions of western Maharashtra, the fruits get spoiled because of black spots and cracks due to humid climate of rainy season.

Ambia bahar is also taken in the Deccan where enough water is available during hot weather. In this case, the fruit is available during June and July and no irrigation is given after the start of the rainy season. The trees shed their leaves by October–November, when a shallow hand digging or ploughing is given. The manure is applied in the month of December–January. The first irrigation is given in January and the flowers appear within a month of this irrigation. In dry arid regions of western Maharashtra, this *bahar* has been found to be better in yield and quality of fruits as compared to *Mrig bahar* fruits.

For *Hasth Bahar*, the trees have to be made dormant during August-September. This is rather uncertain because of the rains that occur during this period. For this reason this *bahar* is seldom taken.

22.7 Flowering, Floral Biology and Pollination

Flowering

In the evergreen pomegranate varieties, flower buds of the spring flush are borne on mature wood of the previous season's growth whereas the flowers which appear during July–August are borne on the current year's growth. In the case of deciduous varieties, flowers are borne on the current season's growth between July and August. In Japanese Dwarf variety, vegetative growth and flower initiation take place simultaneously. The flowers are found mostly in clusters, either terminally or in axils of the leaves (Nath and Randhawa, 1959a). Kulkarni (1920) and Burns (1930) reported three generalised pomegranate flowering seasons in Bombay while Barakzai (1920) recorded two generalised flowering seasons in Sind. Under Delhi condition, Dholka, Kandhari, Muscat White and Patiala flowered only once a year, GB-1 and Japanese Dwarf flowered twice and a double flowered ornamental variety bloomed thrice a year (Nath and Randhawa, 1959a).

Floral Biology

Time of dehiscence varied in different varieties and no general sequence was found with the time of anthesis (Nath and Randhawa, 1959b). In Patiala, dehiscence started prior to anthesis whereas in Muscat White it started afterward. Dehiscence was found to be affected by temperature as well as by atmospheric humidity. Evreinoff (1957) reported that the development of stamens is normal and pollen is fertile in both hermaphrodite and male flowers of pomegrante. Nath and Randhawa (1959b) reported that stigma attained maturity one day before anthesis and receptivity remained at peak on the same and second day after anthesis and it gradually went down till the third day after which it abruptly sank into non-receptivity.

Pollination

Both self- and cross-pollination were recorded in pomegranate. Pomegranate flowers exhibit heterostyly, that is, the style and stigmatic head remain above the staminal column. Gammie and Patwardhan (1929) also indicated that pomegranate is a cross-pollinated fruit. It was also observed that greater percentage of fruit set was obtained both by hand pollination and pollination under natural condition as compared to self-pollination (Nath and Randhawa, 1959c). Pross (1938) working with four pomegranate varieties in central Asia, considered pomegranate to be a self-pollinated crop.

22.8 Pests and Diseases

Pests

Pomegranate trees are attacked by about 45 species of insects in India and unfortunately in this case, fruit is more vulnerable to the attack of pests than any other part of the tree. The most obnoxious enemy is pomegranate butterfly, next in order being bark eating caterpillars. Besides, termites attack the roots ; aphids, whiteflies, scale insects, thrips and leaf defoliators feed on foliage.

Pomegranate butterfly or Anar butterfly (*Virachola isocrates*) (Fruit borer) : It is the most important pest which is constantly and regularly injurious ; widely distributed all over India and is found wherever pomegranates are grown.

The female lays egg singly on calyx of flowers or small fruits. On hatching the caterpillars bore inside the developing fruits and are usually found feeding on pulp and seeds just below the rind. Subsequently, the infested fruits are also attacked by bacteria and fungi causing the fruits to rot. The conspicuous symptoms of damage are offensive smell and excreta of caterpillars coming out of entry holes, the excreta is found stuck around the holes. The affected fruits ultimately fall down and are of no use, even if the fruits be picked before falling down, these fruits have no market value. This is the serious pest and the extent of damage may be as much as to 50-90%.

Application of Metacid 50 EC 1 ml/litre or Carbaryl 0·2% (Sevin 50% WP 4 gm/litre) or Phosphamidon 0·03% (Dimecron 100 EC, 0·3 ml/litre of water) at fortnightly interval is effective.

Bark eating caterpillar : (*Inderbela tetraonis*) has been recorded boring the bark of pomegranate tree and feeding inside. Older trees and the trees in orchards that are not well maintained are more prone to the attack of this pest. Usually, there is only one caterpillar in each hole but there may be 10-12 holes in a badly infested tree. Such trees will bear no fruits.

Keeping the orchards clean and avoiding over crowding of trees help to minimise the attack by this borer. In case of infestation, clean the affected portions by removing all webs, etc., and insert in each hole a swab of cotton wool soaked in carbon bi-sulphide, petrol or even kerosene and seal the holes with mud.

Stem borer : Another common insect which is found in neglected orchards. The caterpillar makes a hole and bores through the branches. Usually, the main trunk or main branches are affected. The presence of the pest is noticed by a small hole on the bark and a network of dried excreta outside the hole. It comes out at night and feeds on bark.

The pest can be controlled by cleaning the hole and extracting the insect by inserting a hooked wire into the hole. The measures suggested against the bark eating caterpillar will prove effective in controlling the beetles as well.

Sap sucking insects : Mealy bugs, scale insects, thrips, aphids, mites are some of the insects reported from various parts of India on pomegranate leaves. Due to the damage by these insects, the trees are devitalised and shed off buds and flowers and small fruits. To prevent the attack of mealy bugs and scale insects from spreading, the affected parts should be pruned and destroyed in the initial stage of attack. If the infestation becomes severe spray with 0·04% Diazinon or Monocrotophos.

White flies and aphids feed by sucking the cell sap from leaves and tender twigs. The affected parts become discoloured and distorted. These insects also secrete copious amount of honey dew on which sooty mould develops, hindering the photosynthetic activity of the plant. Thrips (nymphs and adults) lacerate the leaves, flower stalk, petals and sepals and rasp the sap that oozes out of these wounds. As a result, the leaf tips curl and become dry while flowers are shed and ultimately fruiting capacity of the tree is adversely affacted. To control aphids, white flies and thrips, spray with 0·03% Dimethoate or Phosphamidon. Two sprayings at an interval of 10–15 days will be sufficient to keep complete check of these pests. Red mites can be controlled by spraying with water soluble sulphur 1·25 kg or Kelthane (50%) 500 ml in 500 litres of water.

Leaf eating caterpillars : The leaves of pomegranate trees are often attacked by this pest. Eggs are laid singly on tender leaves usually on lower surface. Freshly hatched caterpillars feed on chlorophyll. Later, they segregate and feed voraciously devouring the entire leaf lamina. In case of severe infestation the young trees may be completely defoliated.

It can be controlled by spraying Rogor or Metacid.

Bagworms (*Clania crameri*) : The caterpillars construct a case over their body and live within, nibbling leaf lamina.

To check the damage caused by the caterpillars, they should be collected and destroyed mechanically. In case of severe infestation dust 10% BHC or spray 0·05% Endosulfan.

Diseases

Fruit spot : The disease is caused by fungus. Affected fruits develop small, irregular spots surrounded by greenish yellow border, which later on turn into strips due to which the seeds below the rind become brownish in colour. As a result, the appearance of the fruit is spoiled.

The occurrance of the disease could be prevented by pruning the dead and affected twigs or branches. Spraying with Dithane M-45 or Captan 500 gm in 200 litres of water after the fruit formation is recommended. The subsequent 3 to 4 sprayings should be given at an interval of 15 days.

Fruit rot (*Phomopsis* sp) : The fungal disease occurs mostly in the rainy season. When the flowers are affected by this disease, they fail to set fruit,

while the young fruits may drop. It's presence is detected by the appearance of yellow or black spots all over the fruit, particularly concentrated at the attachment point of the fruit to the twig. The rind gets depressed due to which the fruit weight decreases sharply. Such badly affected fruits remain immature, under-sized and lose the lustre and finally become soft and start rotting. The disease spreads through the seeds of affected fruit.

The occurrance of the disease could be prevented by pruning all infected twigs and fruits and burning them. Dithane M-45 or Captan should be sprayed at an interval of 15 days.

Leaf spot : The disease is caused by either fungus or by bacteria and are incited by *Xanthomonas punicae* and various fungi like *Cercospora punicae*, *C. granati*, *C. lythracearum*, *Colletotrichum gloeosporioides*, etc. At the early stages, black coloured, indefinite spots appear on the upper surface of the leaves which extend rapidly if the weather is favourable. Affected leaves fall off. Blackish or brownish irregular spots appear on the fruits.

Spray Dithane M-45 or Captan at an interval of 15 days.

22.9 Harvesting and Yield

The fruits are ready for harvest 5–7 months after the appearance of blossoms. The fruits are harvested when the skin turns slightly yellow and the fruit gives a metallic sound when tapped. Each tree bears about 100 fruits, and it continues to give economic crop up to about 25–30 years.

22.10 Packaging

After harvesting, the fruits are graded according to the size. After grading the fruits are packed mostly in bamboo baskets. Boxes made of light wood are also used. Dry grass is used at the bottom and top of the box or basket to set as a packing material. The fruits packed in this manner can be transported over long distance.

22.11 Storage

Pomegranate keeps well for a long time. Experiment showed that fruits stored at 0° and 4·5°C at 80–85% RH did not undergo any shrinkage or spoilage for seven months. They may be sprayed with a 2% lypol solution and

aerated properly before using. In bulk storage, they are packed in layers in wooden crates containing 16-18 kg of fruits and stored at 0°C and 80% RH. Rice straw and paper are used as packing material.

22.12 Breeding and Varietal Improvement

The types of pomegranate under cultivation in the country seem to be of seedling origin from the varieties grown in the neighbouring countries along North-West border. Most of them are known by the names of the places where they are cultivated and cannot be considered as distinct varieties as they are still being largely propagatedby seed, resulting in seedling variation. So the developed grove consists of a mixture of varied types going under one name. They could be more appropriately termed as 'types' rather than varieties.

Improvement of this crop can be done by three methods, viz., (i) collection of superior germplasm from indigenous and exotic sources, (ii) improvement by selection and (iii) controlled hybridisation.

The varietal improvement programme initiated in Maharashtra as back as in 1944 encompassed collection of indigenous and exotic types. The exotic varieties from Baghdad, Palestine, Afghanistan, Iran, Russia and other countries failed to establish. Controlled hybridisation has got great limitations and as such seedling selection work from amongst the local types collected from Alandi in Pune districts and Dholka in Gujarat was taken up. Dr. Cheema did the pioneer work in making selection from the material collected from Alandi which gave rise to GBG-1, now renamed as 'Ganesh' as a chance seedling.

The observed superiority in Ganesh (GBG-1) in respect of prolific yields, medium size fruits with soft seeds, better pulp and sweet juice with an extremely aggreable flavour is not comparable to imported fruits of exotic varieties, particularly in regard to size and quality of fruits.

The Muscat variety of pomegranate is not only famous in Kolhar region of Ahmadnagar district but in the entire Maharashtra due to its large fruits, sweetness and soft seediness. The orchards in this region are mainly from seedling and that is why there is considerable heterozygosity amongst the plants. Due to this heterozygosity, there appears to be large variation in fruit characters. This situation naturally offered a great deal of scope for improvement of pomegranate by resorting to seedling selection (as selection is in fact the rejection of all undesirable types) and subsequently propagating them clonally. For this, initial survey was carried out during 1971 in the orchards of progressive farmars with a view to locate desirable types. In 1972, individual trees of these orchards numbering 47 were marked on the basis of fruit quality. The progeny raised has been planted at Central Campus, Agricultural University,

Rahuri. Uptill now 22 promising selections have been made. Some of them are summarised below :

Sl. No	Type	Fruit colour	Fruit wt. (gm)	Grain wt. (gm)	Juice %	TSS %
1.	P-23	Greenish-yellow with pink tinge	385	265	83·50	16·0
2.	P-26	—do—	379	251	84·19	15·5
3.	P-16	—do—	340	228	83·12	16·5
4.	SK-1	Yellow with pink tinge	343	234	78·56	16·0
5.	P-13	Greenish-yellow with pink tinge	325	211	82·98	16·0

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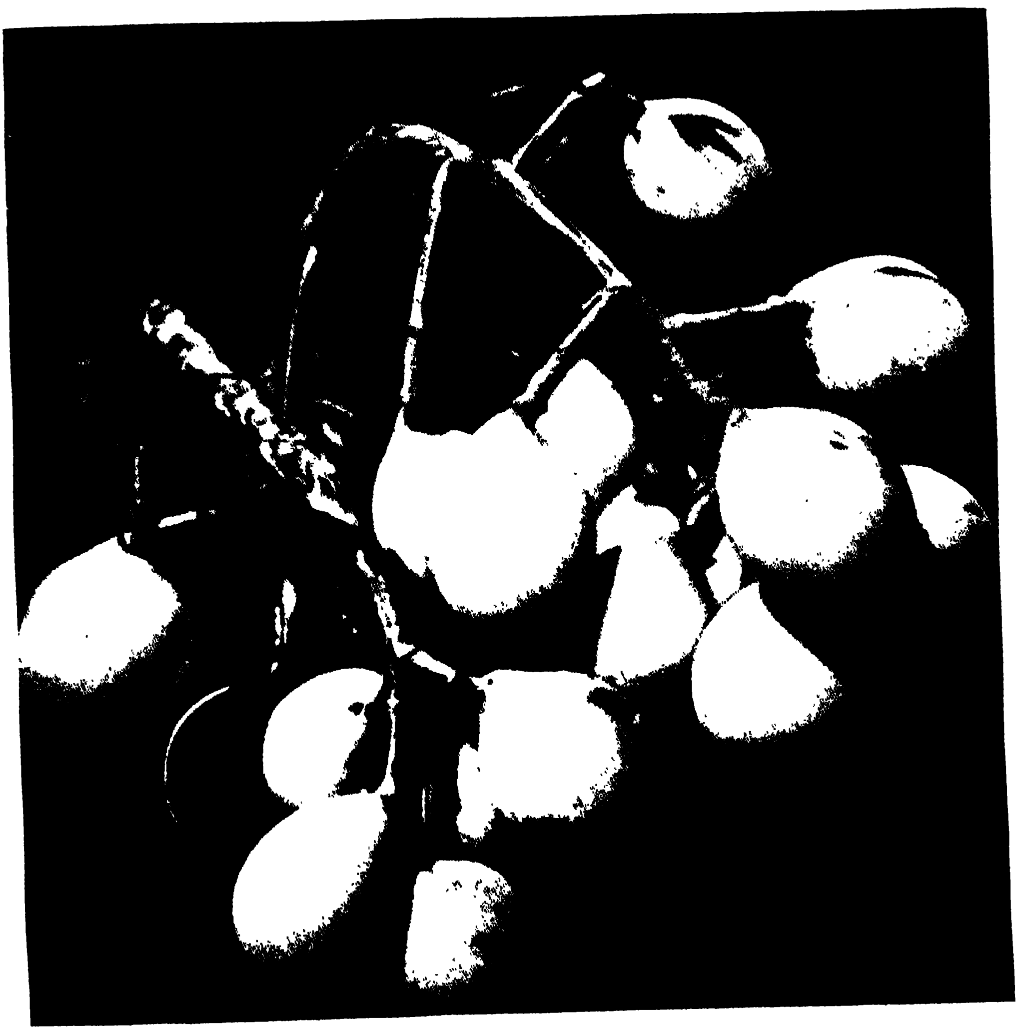
Flowering on loquat



Fruits of loquat

23

LOQUAT

R. K. PATHAK and HARI OM GAUTAM

The loquat is grown extensively throughout the subtropical regions of the world. It is also known as Japan plum.

23.1 Composition and Uses

The fruits are generally used for dessert purposes as well as for making jam, jelly, preserves and canning. *Chutney* is also made from semi-ripe fruits. The loquat jelly is an important product because the fruits are good source of acid and pectin. The fruit consist of pulp 60–70 per cent and seed 15–20 per cent. The edible parts of fruit contain 87·4 per cent water, 10·2 per cent carbohydrates, 0·7 per cent protein, 0·3 per cent fat, 0·5 per cent mineral, 0·9 per cent fibre, 0·03 per cent calcium, 0·02 per cent phosphorus and 0·7 mg iron/100 gm (Rajput and Singh, 1964).

23.2 Origin and Distribution

Among the subtropical fruits, loquat (*Eriobotrya japonica* Lindl.) is an important fruit, belonging to the family Rosaceae. It is indigenous to the hills of mild winter and moist regions of Central Eastern China (Meyer, 1911). The loquat has long been grown in Japan and China and several important varieties have originated in these two countries, particularly in Japan.

The exact date of its introduction in India is not known. However, Government Botanical Gardens (now Horticultural Experiments and Training Centre) Saharanpur, Uttar Pradesh is said to be the first garden to grow it, from where it has been distributed all over the country (Randhawa and Singh, 1970). The loquat was introduced in this country under the name of 'Japan plum' or 'Japanese medlar'.

Besides China and Japan, loquat is now grown extensively throughout the subtropical regions of the world. It is commercially grown in the Mediterranean region, Australia, South Africa, South America, California and India. (Condit, 1915 ; Srivastava, 1957 and Kaempfer, 1972). The commercial cultivation in India is mostly confined to Uttar Pradesh (Saharanpur, Dehra Dun, Muzaffarnagar, Meerut, Farrukhabad, Kanpur and Bareilly), Delhi, Punjab (Amritsar, Hoshiarpur and Gurdaspur) and Himachal Pradesh (Kangra). It is also grown to a limited extent in Assam, Maharashtra and Tamil Nadu (Nandi hills).

23.3 Species and Varieties

Species

Loquat (*Eriobotrya japonica* Lindl) belongs to the family Rosaceae and sub-family Pomoideae (Lindley, 1882). Kaempfer (1972) described this under the name of *Mespilus japonica*. The word *Eriobotrya*, derived from two Greek words, 'erion' (wool) and 'botrys' (cluster) is implied to woolly inflorescence.

The genus *Eriobotrya* has other species—*E. petiolata*, *E. latifolia*, *E. longifolia*, *E. hookeriana*, *E. dubia*, *E. bengalensis*, *E. angustissima*, *E. elliptica* and *E. japonica*. *Eriobotrya angustissima* is an evergreen shrub found at an elevation of 1,300-1,700 m in Assam and *E. dubia*, a small tree occurring slightly at higher elevation in the eastern Himalayas, also bears edible fruits.

Varieties

The loquat varieties have been grouped on the basis of their origin and time of maturity, and these have been described below.

(a) Chinese group : The fruits are large, pyriform and deep orange coloured.

(b) Japanese group : The fruits are small, slender and light coloured.

Early season varieties

Maturity in these varieties starts from the middle of March.

Golden Yellow : Tree tall, upright to spreading, vigorous, crown oval and compact ; leaves lanceolate, remotely toothed ; fruit medium, oval to oblong, golden yellow in colour ; pulp medium, pale orange, smooth, soft ; taste mild, subacid with few seeds.

Improved Golden Yellow : Tree tall, spreading, vigorous, crown oval and open ; leaves lanceolate to elliptic-lanceolate, remotely toothed ; fruit large, oval to pyriform, orange-yellow in colour ; pulp thick, orange colour, smooth, crisp ; mild taste, subacid, moderately seedy.

Pale Yellow : Tree medium, upright to spreading, vigorous ; leaves oblanceolate, remotely toothed ; fruit large, oblong-pyriform ; pale yellow ; pulp thin, creamy white, smooth, melting, subacid, pleasant flavour, moderately seedy.

Large Round : Tree spreading, vigorous, crown uneven and compact ; leaves elliptic-lanceolate, serrate ; fruit medium, ovate globose, yellow ; pulp thin, creamy white, coarse, firm ; taste mild, subacid.

Thames Pride : Tree tall, upright, vigorous, crown broad, dome shaped ; fruit medium, pyriform, deep yellow ; pulp medium, pale orange, coarse ; taste mild, subacid, moderately seeded.

Mid-season varieties

The maturity of fruits starts from last week of March.

Safeda : Tree medium to tall, upright, vigorous, crown rounded : leaves elliptic-lanceolate, serrate ; fruit large, oblong-pyriform ; pulp thick, creamy white, smooth, melting ; taste excellent, subacid, moderately seeded.

Fire Ball : Tree tall, upright, moderately vigorous, crown semiglobose and compact ; leaves elliptic-lanceolate, serrate ; fruit small, oblong to ovate, saffron yellow ; pulp thick, smooth, crisp ; taste mild, subacid and moderately seedy

Improved Pale Yellow : Tree large, spreading, moderately vigorous, crown oval and open ; leaves elliptic-lanceolate, serrated ; fruits medium, oblong-pyriform, pale yellow ; pulp medium thick, creamy white, smooth : firm, taste subacid and moderately seedy.

Mammoth : Tree tall, upright, moderately vigorous, crown uneven, compact ; leaves elliptic-lanceolate, slightly serrated ; fruits small, oblong-pyriform, colour snowshoe ; pulp medium thick, pale orange, coarse, granular, pleasant taste, subacid, few seeds.

Late season varieties

California Advance : Tree dwarf, upright, moderately vigorous, crown round and open ; leaves oblanceolate, remotely toothed ; fruit medium, oblong-pyriform, pale yellow ; pulp thick, creamy white, smooth, melting ; taste excellent, subacid, few seeds.

Tanaka : Tree dwarf to medium, upright, moderately vigorous, crown semiglobose and compact ; leaves elliptic-lanceolate ; fruit small, ovate, orange coloured ; pulp medium, yellow, coarse, firm ; taste pleasant, subacid, moderately seedy.

23.4 Soil and Climate

Soil

Loquat thrives on wide range of soils, but well drained, deep, sandy loam soils rich in organic matter are ideal for its cultivation. Oppenheimer (1947) suggested

that instead of very light soils, medium heavy soils with perfect drainage is to be preferred. Loquat does not succeed well, if the sub-soil has gravel, hard pan or excessive lime.

Climate

Loquat is highly exacting in its climatic requirement. A milder subtropical climate with an average rainfall of 60 to 100 cm well distributed throughout the year is best suited for its normal growth and fruiting. Since flowering takes place from October to late January, at certain places the crop may be destroyed by moderate winter frosts. The plants are permanently injured when the temperature falls to zero and remains for any length of time. The fruit is most susceptible to frost injury when it just starts colouration. In places where summer sets in early and scorching hot winds begin to blow before the fruits ripen, the fruits remain very small and do not mature properly.

23.5 Propagation

Seed

The loquat is generally propagated from seeds. After extraction from fruits the seeds should be immediately sown as exposure to heat and light tends to result in poor seed germination. Due to high cross-pollination, seedling trees should not be used for commercial cultivation.

Vegetative propagation

Air-layering

Propagation of loquat through air-layering is easy. In this, 3 month-old shoots are ringed and layered. Treatment of ringed shoots with 3 per cent NAA or 2,500 ppm IBA (Singh *et al*, 1961 and Srivastava, 1957) has been recommended for improved rooting.

Rootstocks

The promising loquat varieties are generally propagated on seedlings of commercial varieties. Several other rootstocks such as apple, pear, *Mespilus* and *Cydonia* have also been used in certain occasions (Randhawa and Singh, 1970). The quince has long been used as dwarfing stock in Europe, Japan, Australia and California. Besides controlling tree size, quince rootstocks are also tolerant to most of the pests and diseases (Assaff and Rivals, 1977). However, in plains of Uttar Pradesh, quince had proved entirely unsuccessful (Singh, 1959).

Grafting

Inarching is the simplest form of grafting and is, therefore, commonly practised. In the early years, Sato (1907) stated that top grafts, root grafts and cleft grafts were generally employed in Japan. Hence these methods should also be tried systematically.

Budding

Shield budding, using buds from three month-old branches in January and February gave encouraging success, while poor success was observed during September-October. Ring budding can also be used (Singh, 1959 ; Randhawa and Singh, 1970).

Top working

A large percentage of loquat trees from seedling with poor fruit quality are commonly seen. These uneconomic trees can be converted to profitable ones by topworking with promising varieties. After beheading the seedling trees, several methods such as shield budding, cleft grafting or bark grafting could be employed. However, bark grafting has been found to be more successful as compared to other methods (Randhawa and Singh, 1970).

23.6 Cultivation

Planting

In general, loquat is planted at a distance of 6-8 metres. The field should be levelled and pit of 75 × 75 × 75 cm size should be dug during May.

After exposure for 15-20 days, the upper soil of the pit is mixed with 40–50 kg well rotten farm-yard-manure and 200 gm of single superphosphate. If there are possibilities of termite infestation, then BHC or Aldrin dust 50 gm/pit should also be added. In these pits, healthy plants are planted either in mid-August or mid-February.

Training and pruning

Loquat is generally trained by central leader or open system. In the initial stages, stem up to height of 45-50cm should be kept clean. In the fruiting plants, pruning is confined to removal of dead and diseased branches. Harvesting of mature bunch is a kind of pruning and it encourages new growth.

Irrigation

Loquat requires judicious irrigation. There must be sufficient moisture in the soil in order to enable the shoots to develop and the mature terminal buds to

fill out properly. As the trees blossom early, the orchard must be irrigated just before the swelling of blossom buds (Randhawa and Singh. 1970).

During fruit growth to maturity, maintenance of proper moisture regime by frequent irrigation is advisable.

Manuring and fertilisation

Loquat trees produce heavy, luxuriant foliage and large amount of fruits. When the tree begins to bear heavy crops, adequate manure and fertilisers should be incorporated. Singh (1952) suggested that production of 445 kg loquat fruits would require 365 gm N, 360 gm P_2O_5, 1·35 kg K_2O and 325 gm of CaO, besides the additional requirement for the vegetative growth. Application of nitrogen at 80 and 120 gm per plant to one-year-old loquat plants vars. Golden Yellow and Tanaka Japan in the form of urea proved effective in improving height and spread of plant, number of branches, leaf and leaf area. Treatment with 120 gm nitrogen increased leaf nitrogen and showed a positive correlation between N content of leaf and level of fertilisation (Singh and Pandey, 1979). Calcium deficiency symptoms of loquat was reported by Sato *et al*, (1960) ; however, excess calcium did not show any detrimental effect on tree growth.

Interculture

The soil should be kept in good physical condition by thorough cultivation, addition of organic matter and by proper irrigation. Loquat prefers clean cultivation as compared to other methods of orchard management. However, cultivation of leguminous cover crops during winter and summer is advisable (Randhawa and Singh, 1970). The orchard can be kept clean by timely hoeing and weeding. Deep ploughing should always be avoided.

23.7 Flowering, Pollination and Fruit Set

Loquat bears flowers on new year's growth. The first flush of flowers can be noticed during August-September ; however, due to non-viable pollen grains there is no fruit set. The second flush of flowering takes place during October-November and sets maximum fruits. Another flush of flowers can also be noticed during December–January but hot and dessicating winds in early summer have adverse influence and thereby reduce the fruit size.

Pollination and fruit set

It is a common observation, that loquat trees growing singly or in small groves, though produce perfect flowers, yield negligible or no crop. This

behaviour was suspected to be due to self-incompatibility and in loquat it is of gametophytic nature. On the basis of fruitfulness, the loquat varieties were classified by Singh (1955) into two groups, i.e., (a) self-incompatible—Golden Yellow, Improved Golden Yellow, Pale Yellow and Large Agra (b) partial self-incompatible—Large Round, Fire Ball, Thames Pride, California Advance and Tanaka.

The variety California Advance proved to be the best polliniser for Tanaka. It was interesting to note that Tanaka when pollinated with Pale Yellow gave lower set than the self one, indicating thereby a partial cross-incompatibility. Golden Yellow though completely self-incompatible gave the highest setting when pollinated with California Advance (Sato, 1907).

23.8 Fruit growth and Development

After fertilisation, the loquat fruit develops very rapidly. The first indication of fruit enlargement is thickening of toral rim immediately above the carpel level. The whole toral region undergoes cell division and enlargement uniformly throughout (Smock, 1937). The sepals grow towards the centre and cover in 'hood' fashion the distal portion of the carpels. The sepal bases thicken and persist as permanent structures whereas the petals, stamens and styles dry up. The hood or cap enclosing the distal portion of the carpels can be excised from immature fruits and five carpels are exposed to view. The functional ovules develop into fertile seed occupying the whole central region of fruit (Randhawa and Singh, 1970).

The edible portion in loquat is entirely toral in nature, consisting of pith and cortical areas. The development of edible portion consists of rather uniform growth of receptacle tissue throughout the fruit. The toral cells of mature fruits are large, thin walled and very juicy.

Spraying of 2, 4, 5-T at 20 and 40 ppm has been found very effective in reducing the fruit drop and hastening the fruit maturity (Singh *et al*, 1960).

Attempts have also been made to develop loquat fruits parthenocarpically. Spraying of 100–200 ppm GA_3 induced seedless fruit development. However, these fruits were smaller in size as compared with normally pollinated and fertilised fruits (Kumar, 1976).

Thinning of fruit

In loquat, the flower buds are produced at the terminal end of season's growth and fruiting takes place in clusters. Hence it is impracticable to thin out few fruits, so that each fruit would have sufficient space for its proper development. Under these circumstances, it is advisable to clip out terminal end of branches whenever there is overcrowding. The thinning should be practised early in the fruiting season.

23.9 Pests and Diseases

The loquat in India is almost free from serious pests and diseases.

Pests

Fruit flies, aphids and scale-insects have been reported attacking the loquat. None of these are, however, very severe in India. Bark-eating caterpillar is sometimes a common pest. This can be controlled by injecting kerosene oil or a mixture of equal parts of creosote and chloroform or petrol into the bored holes with the help of a syringe. Cotton or wool soaked in carbon disulphide or chloroform can also be used inside the holes to kill the caterpillars. For avoiding the trouble of injecting in individual holes, Singh *et al*, (1963) suggested spray of 0·1 per cent parathion emulsion.

Diseases

The common disease of loquat is collar rot caused by *Diplodia natelensis.* The fungus attacks the bark at collar region which turns brown, cracks and sometimes peels off. The entire tree may eventually be killed. For controlling this malady, the infected portions should be scraped and painted with solution containing Fytolan 225 gm, lime 112 gm, water 2·27 litres. (Randhawa and Singh, 1970).

23.10 Harvesting

The fruits should be left on tree until they are fully mature and maximum amount of sugar is developed. Harvesting of immature loquat fruits should be discouraged. All fruits in a cluster usually mature uniformly and therefore, the entire cluster may be cut. However, in some cases where the fruits at the base ripen before those at terminal end of cluster, care is to be taken to harvest only mature fruits by clipping.

23.11 Yield

The loquat tree starts bearing fruit generally from the fourth year of planting. The yield increases as the tree grows older and the maximum yields are obtained when the trees are about 15 years old. The average yield of fruit is about 16–20 kg/tree. However, a healthy well managed tree should give 30 to 40 kg fruits.

23.12 Breeding and Varietal Improvement

In India, work on hybridisation in loquat was initiated at the Horticultural Research Institute, Saharanpur in the year 1953. It was reported that the varieties Improved Golden Yellow, Indian selection and California Advance, a selection of California, were crossed and hybrid plants obtained. The crossing of different varieties was made with a view to combine the colour of Golden Yellow with the keeping quality of California Advance. The above two varieties were also crossed with Tanaka, a Japanese variety to combine the size of the fruit of Tanaka with the colour of Improved Golden Yellow and keeping quality of California Advance. The hybrids obtained from them were grown successfully (Anon., 1950-53).

At Saharanpur, out of the crosses made, 550 hybrid seedlings were obtained, 21 plants fruited in 1960, among which 6/2 (Tanaka × California Advance), 8/2 and 8/4 (Tanaka × Golden Yellow) were found promising in respect of fruit size, taste, flavour and TSS content.

Hybridisation work was continued at Saharanpur. Improved Golden Yellow, the well known commercial variety was reciprocally crossed with Thames Pride with a view to impart the heavy fruiting character of the latter. Of 1,162 flowers thus crossed, 292 fruits having 721 seeds were obtained. Thirty F_1 hybrids from previous crosses flowered and bore fruits. Nine of these showed promising characters (Anon., 1960-62)

Crosses were also made between Improved Golden Yellow × Tanaka; Tanaka × Improved Golden Yellow; Improved Golden Yellow × California Advance; California Advance × Improved Golden Yellow. Out of 1,500 crosses made, only 260 fruits were obtained which produced 590 seeds (Anon., 1960-62).

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Fruiting branchess of Phalsa

Phalsa orchard after pruning

24

PHALSA

GAURI SHANKAR

Phalsa (*Grewia asiatica* L.) is known by different names in different Indian languages, such as Bengali (dhamani), Punjabi (phalsa) etc. In Vedic writings too there is a mention of phalsa. In India, different parts of the plant are used for curing variety of ailments.

Phalsa is commercially cultivated in the states of Punjab, Haryana, Rajasthan, Uttar Pradesh and Madhya Pradesh. Besides these states, it is also cultivated on limited scale in the states of Maharasthra, Gujarat, Andhra Pradesh, Bihar and West Bengal.

24.1 Composition and Uses

Ripe phalsa fruits are sub-acidic and good source of vitamin A and C. They are fair source of phosphorus and iron. Fruits contain 50-60 per cent juice ; 10–11 per cent sugar and 2·0–2·5 per cent acid (Aykroyd, 1963). The fruits are excellent for making juice and squash. However, it is mostly used as fresh fruit and have cooling effect.

The shoots of the plants after pruning can be utilised either for making baskets or supporting vegetable crops. Pruning of one full grown plant is sufficient for making one large or two small baskets. Phalsa baskets are fairly strong and can be used for transporting fruits and vegetables. Ropes can also be made from the bark after treating if, which yields fibre.

24.2 Species and Varieties

Species

Phalsa belongs to the family Tilliaceae and several members of this family are indigenous to India. There are 18 genera and 400 species which are mostly

distributed in tropical and subtropical regions of the world. The genus *Grewia* has 140 species, out of which 40 occur in India. However, only *Grewia asiatica* L. (phalsa) is of commercial importance.

Varieties

There is no distinct variety available in phalsa (Singh, 1974). Some growers have, however, given names as 'Local' and 'Sharbati'. Two distinct types, i.e., Tall and Dwarf were recognised at Hissar and the Dwarf type was found to be more productive. The comparative data on growth and fruit characters are given in Table 1.

TABLE 1. CHARACTERISTICS OF TWO TYPES OF PHALSA (Anon, 1981)

Characters	Tall type	Dwarf type
Plant height (m)	4·5	3·4
Internode length (cm)	101·6	97·6
Leaf size (cm)	20 × 18	18 × 15
Lower leaf surface	Light green	Greenish white
Fruit yield (kg)	5·2	3·5
Fruit size (cm)	20·7	22·6
Fruit weight (gm)	0·478	0·544
Pulp (%)	81·5	60·3
Juice (%)	5·4	34·6
TSS	14·0	12·1
Acidity	4·64	3·63

24.3 Soil and Climate

Soil

Phalsa is not very exacting in its soil requirement, thus can be grown on a wide range of soils, even on moderately alkaline soils. Fields where other fruit crops are unsuccessful, phalsa can be grown with success. However, best results are obtained in well drained, loamy soils. Under water logged conditions plants become chlorotic and make poor growth.

Climate

Phalsa does best in regions where there is distinct winter and summer. The yield and fruit quality are better in such regions. In regions having no winter, the plant does not shed leaves and produce flowers more than once. The quality and yield are poor in such conditions. Full grown plants can tolerate freezing

temperature, for a short period. The plants can tolerate temperature as high as 44°C and high temperature favours ripening of the fruits. It requires clear weather at the time of flowering. Rains at the flowering time affect setting of fruit.

24.4 Propagation

Seed

It is commercially propagated by seed. Seedling plants are fairly true to type. Freshly extracted seeds should be used for raising seedlings. Seeds lose their viability under ordinary storage after 90–100 days. The viability of seeds can be retained for a period of 6 months under cool storage. Seeds require 15-20 days for germination and seedlings get ready for planting in the field by 3–4 months.

Vegetative

Cutting

Several vegetative methods are reported to be successful in phalsa. Jauhari (1960) reported that treating phalsa cuttings with 100 ppm indole butyric acid (IBA) for 24 hours yields 60 per cent success whereas Singh *et al*, (1961) recorded as high as 68·8 per cent success from hard wood cuttings treated with 100 ppm IBA. Singh and Kumar (1967) obtained 72·5 per cent rooting in cuttings when shoots were ringed 15 days before planting and treated with 2,500 ppm IBA. Recently, a report from Rajasthan Agricultural University, Udaipur claims 76·2 per cent success with hard wood cuttings, treated with 250 ppm Ethrel for five minutes followed by 3,000 ppm IBA for two minutes (Anon., 1981).

Layering

Air-layering has been tried by some workers. Saxena (1963) reported that air-layering yielded 50 per cent success when the air-layers were treated with a mixture of IBA, NAA, 2, 4 D and boron 10,000 ; 10,000 ; 1,000 and 100 ppm respectively, the untreated air-layers failed to root. Mohammad and Chauhan (1970) recorded 85 per cent success when air-layers were treated with a mixture of IBA and NAA at the rate of 1,500 ppm each, but when the same mixture was used for ground-layering success was 50 per cent only. Chatterjee and Rao (1980) recorded 80–90 per cent success by treating the air-layers with IBA or NAA at 5,000 and 10,000 ppm.

Grafting

Amin (1978) reported a technique of soft wood grafting for phalsa in which rootstocks were grown *in situ* for a year or more and pre-defoliated (10 days before operation) scion were grafted. He recorded 100 per cent success in this method.

24.5 Cultivation

Planting

Plants can be planted either during July–August or February-March when the plants have shed their leaves. Eight to twelve months old seedlings are better for planting in the field.

Usually, planting is done 2·5–3·0 metre apart both ways, thus, accommoda-ting about 1,100-1,500 plants per hectore. However, phalsa is well suited for close planting (high density planting), as it completes flowering and fruiting within 4–5 months.

Higher yield per unit area can easily be obtained from phalsa by increasing the plant population. For increasing the plant population, paired row planting system has been tried at Allahabad Agricultural Institute with great success. In paired row planting, two plants are planted at one place at a distance of 0·60 metre. The second pair of plants are planted at a distance of 3 metre from the first pair of plants. The distance between rows is maintained at three metres. By adopting this method of planting, the number of plants per unit area is nearly doubled with little loss of yield per tree. Due to increased plant population, the total yield is increased by 20–30 per cent.

Pruning

Pruning is one of the important cultural operation in phalsa cultivation. Annual pruning is essential for securing high yield of better grade fruits. The desirable height for pruning is 0·9–1·2 metres from the soil surface. Reports from other parts of the country are in agreement as regards the height of pruning (Hayes, 1957 ; Singh and Sharma, 1961). Plants can be pruned any time during December or January when they are dormant. Singh and Sharma (1961) also suggested the same period for pruning.

Irrigation

Phalsa is regarded as a drought resistant crop. However, it has been observed that in northern India irrigation is essential for securing high yield of better grade fruits. Plants do not require any irrigation till January. The first irrigation is needed in the second or third week of February after the application of fertiliser. During March and April, irrigation after every 20 or 25 days seems to be beneficial. However, during May, irrigation after every 15 or 20 days is desirable.

Manuring and fertilisation

Phalsa is commonly not fertilised by growers. Moreover, reports on its manuring is also scanty. Hayes (1957) was of opinion that phalsa responds to

manuring. The crop is borne on new growth and application of manures and fertilisers will encourage vegetative growth. Nijjar (1969) reported that application of 1·0 kg nitrogen per plant as farm-yard-manure or CAN or their combination gave high yield. Gupta (1974) found that 15 kg farm-yard-manure applied soon after pruning followed by 125 gm nitrogen per plant, just before bud sprouting, was optimum for good yield. The effect of different levels of N, P and K on vegetative growth, flowering, flruit-set, fruit quality and leaf composition of phalsa was studied by Sadhu *et al*, (1975) in sand culture. The plants under N, P or K deficiency showed stunded growth with less number of branches and leaves, the effect of N was more pronounced than that of P or K. N, P or K starved plants failed to flower. Pundir and Pathak (1981) recorded high yield by application of N, P and K at 100, 40 and 25 kg respectively per hectare. Trials at Rajashthan Agricultural University, Udaipur also revealed that application of 100 : 40 : 25 kg NPK per hectare gave higher yield. (Anon., 1983).

Among the micro-nutrients, zinc and iron were found to influence berry size and juiciness. Singh *et al*, (1981) reported that application of 0·4 per cent $ZnSO_4$ at pre-bloom stage and after berry set improved the juice content. Application of 0·4 per cent $FeSO_4$ alone or in combination of zinc improved the berry size.

Intercropping

It is desirable to grow green manure crops such as *moong*, cow pea or *urid* during the rainy season in early life of orchard. The green manure crop should be turned in towards the end of rainy season.

Weeding

One-two ploughings after pruning the plants is desirable to control weeds and to incorporate farm-yard-manure or compost. If necessary, one ploughing may be given after first irrigation to mix fertilisers and control weeds.

24.6 Pests and Diseases

Pests

Phalsa is free from serious pests and diseases. The only pest which is serious on phalsa is bark eating caterpillar (*Inderbela* sp.) which makes tunnels in the main branches or trunk. The affected plant part dries after sometime, if not attended, due to the girdling effect. This can easily be controlled by injecting kerosene oil or petrol in the holes and plugging them in the months of December and January after pruning. The operations should be repeated each year. The other insect which does considerable damage to foliage is brown beetle (*Anomala* sp.). It is more severe during rainy season and can be controlled by spraying Dieldrin 0·1 per cent.

Diseases

Among the diseases, brown spot of phalsa caused by *Cercospora grewiae* is common (Srivastava and Mehta, 1951). The disease causes premature leaf fall, particularly during the rainy season. On the leaves of the affected plants tiny lesions appear on both sides of the leaf, which afterward cover a large area with white mass. It can be controlled by spraying Dithane Z-78 at the rate of 0·3 per cent.

24.7 Harvesting

The crop starts ripening by the last week of April when limited fruits are in the market. This ensures a better price to the growers as there is not much competition. The period of harvesting continues up to the first week of June. It is essential to collect the ripe fruits daily from each plant. The ripe fruits are highly perishable and therefore, they should be marketed as soon as possible.

24.8 Yield

The average yield from a mature plant in single row system is 6·0 to 7·0 kg whereas the average yield per plant in double row planting is lower (4–5 kg) in comparison to single row system. However, the total yield per unit area is much higher because of increased plant population.

Use of growth substance

Application of growth substances has proved effective in increasing the fruit set and yield in phalsa. Treatment with GA_3 at 10 ppm and 2, 4, 5-T at 5 ppm increased the setting of fruit and also the yield (Randhawa, *et al*, 1959). Studies at Allahabad Agricultural Institute showed that the use of Cycocel at 250 ppm sprayed twice at an interval of 7 days after 50 per cent fruit-set increased the fruit size. It also caused delay in fruit maturity by 3-5 days. Application of 1,000 ppm Ethrel resulted in maximum (71·1%) ripening in 5 days after application (Singh *et al*, 1979) Chundwat and Gupta (1974) recorded improvement in yield and fruit quality by the use of 1,000 ppm SADH at early stage of plant growth and it also reduced the plant height.

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25

DATE PALM

O. P. PAREEK

Date palm is a prominent tree of the desert oases. In India, dates are almost exclusively imported from the Near-East and North African countries where it is the mainstay for the economy. Date has been a staple food of the population extending from western Iraq across Arabia and North Africa.

25.1 Composition and Uses

It provides nutritive fruits rich in sugar, iron, potassium, calcium and nicotinic acid. Small amounts of protein, copper, magnesium, chlorine, sulfur, vitamin A, B_1 and B_2 are also present in date pulp. The flesh of dates with a moisture content of 20 per cent contains from 60–65 per cent sugar, about 2·5 per cent fibre, 2 per cent protein and somewhat less than 2 per cent each of fat, mineral matter and pectic substances (Nixon and Carpenter, 1978). Such fruits provide about 3,150 calories per kg.

In Iraq, alcohol, a liquor known as 'arak', vinegar, liquid sugar, date juice known as 'dibbis' from the date pulp and a concentrate protein for poultry birds from date stone are manufactured. In California, diced date, date paste and sugar are manufactured for use in breakfast food and bakery items. The leaves of the palm also have potential for use in the manufacture of paper.

25.2 Origin and Distribution

Date palm is believed to be indigenous to countries around the Persian Gulf. Its culture was probably established as early as 3000 B.C. in Iraq (Mesopotamia). It has also been under cultivation in Egypt since the prehistoric days but here it assumed importance sometime later than in Iraq. Excavations of Mohenjodaro revealed that this fruit was in Indo-Pakistan as early as 2000 B.C. In the Old

Date-palm in bearing

World, the regions where dates are grown commercially in large quantities stretch from Indus Valley in the East through the southern edge of the Turko-Perso-Afghan mountain, Iraq, Kirkuk-Haifa oil pipe and along the coastline up to Tunisia and then skirting the southern edge of the Atlas to the Atlantic. Southwards, the date lands fall up to Sudan, then follow the coast of the Red Sea and Gulf of Aden, northern part of Somalia and southern coast of Arabia. Date palm was introduced into the western hemisphere in the late eighteenth or early nineteenth century by the Spanish Missionaries. Dates were also introduced in the Atacama Desert and other parts of South America, Kalahari Desert of South Africa and the Great Central Desert of Australia. At present, the principal date growing countries of the world are Iraq, Saudi Arabia, Algeria, Iran, Egypt, Libya, Pakistan, Morocco, Tunisia, Sudan, USA and Spain having about 60 million palms. Of this, about one-third number is only in Iraq.

In the Indus Valley, date-palm is believed to have been introduced by the soldiers of Alexander the Great in the 4th century B.C. and also by the Moslem invaders at the beginning of the 8th century A.D. Almost all of this area is now in Pakistan. There are no commercial plantations of good dates in India. Wild groves of seedling date-palm are found on the coastal belt from Anjar to Mandvi in Kachchh district of Gujarat (Pareek, 1984). It is believed that Turk settlers brought dried dates during Haj pilgrimage and sowed their seed in their fields in Kachchh and this resulted in these groves. It is estimated that about one million palms are growing on this coastal belt producing about 10,000 tonnes of dates. Introduction of better varieties of date-palm from the USA, Pakistan and the Middle East countries were made during 1955 to 1962 at Regional Fruit Research Station, Abohar, under the aegis of the Indian Council of Agricultural Research. Further importation of date suckers was started since 1978 under the All India Co-ordinated Fruit Improvement Project of the ICAR with the assistance of UNDP at Bikaner and Jodhpur in Rajasthan, Abohar in Punjab, Hisar in Haryana and Mundra in Kachchh.

25.3 Species and Varieties

Species

Date-palm belongs to Palmae family and is botanically known as *Phoenix dactylifera* L. and has 36 chromosomes in diploid condition. There are about 12 species of *Phoenix* which are native to tropical or subtropical parts of Africa or Southern Asia. A very closely related species, *P. sylvestris* (L) Roxb., is widespread in India and is an important source of jaggery and a drink called *tadi*. *P. canariensis* Chabaud (Canary Island palm) is a well known ornamental palm. Unlike in these two species, *P. dactylifera* palm produces axillary offshoots

or suckers which chiefly arise near the base of the stem. Some of the other species found growing wild in India are *P. farinifera* and *P. humilis*. Date-palm is monocotyledonous.

Varieties

There are probably not less than 1,000 varieties of date-palm in the world but only a few are extensively grown. These varieties, depending on flesh consistency, are divided into three groups, namely, soft, semi-dry and dry. In soft varieties like Halawy, Khadrawy, Medjool, Shamran (Sayer), Saidy and Hayani, almost all cane sugar is converted to invert sugar or reducing sugar during the process of ripening. Thus, these are also called 'invert sugar' dates. The dry and semi-dry varieties like Thoory, Deglet Noor, Zahidi and Dayri retain a good amount of sucrose on full ripening and are, therefore, called 'cane sugar' dates. As much as one-third of the total sugar may be sucrose in the fruits of the semi-dry variety Deglet Noor and the dry or 'bread type' Thoory.

The varieties Zahidi, Sayer, Halawy and Khadrawy are commonly grown in Iraq. Hayani is extensively grown in Nile Delta of Egypt, Saidy in Libyan desert, Medjool in Morocco and Deglet Noor in Algeria and Tunisia.

In India, date varieties came from the Middle East countries and North Africa directly or via California. Only 34 named varieties are there in India, besides the rich seedling variability in Kachchh district of Gujarat. Almost all the fruit in India is at present harvested at *doka* stage (full grown, hard, yellow or red) and is consumed as fresh fruit. This is essential because the fruit, if left on the tree beyond the middle of July, will be spoiled owing to monsoon rains. At this stage, the fruit in a large number of varieties is astringent. A few varieties having non-astringent and sweet fruit like Halawy and Barhee are preferred. Other such varieties are Chip Chap (Kip Kap), Shaker, Bureim and Shahaani. The varieties like Medjool, Zahidi and Khadrawy have been found suitable for processing to prepare *chhuhara*. The variety Zahidi has been found suitable for processing to prepare *pind khajoor*.

25.4 Soil and Climate

Soil

Deep sandy loam soils are considered the best for date growing. However, dates can be grown in wide range of soil types. Maximum water holding capacity and good drainage are desirable. Date-palm can grow in alkaline and saline soils but in such soils its growth and productivity are greatly reduced. Date groves have been raised in the sandy and shallow soils underlain with *murram* (*kankar*) at a depth of 50–100 cm in the Thar Desert of India. Date-palm groves are also found in the coastal soils in Kachchh.

Climate

Successful date culture requires moderate winter temperature and long hot summer to mature the fruit. It can withstand summer temperature as high as 50 °C. Date leaves are injured by prolonged temperatures of $-6{\cdot}7$ °C or below. Serious defoliation occurred in Arizona under temperatures of -10 to -8 °C with duration of 12 hours (Tate and Hilgeman, 1962). The ideal mean temperature during flowering and ripening of fruit is between 25–30 °C, depending on variety. The heat requirement to ripen the fruit varies with variety and a range from 4,200 to over 5,000 summation heat units (above a base 10 °C). In most of the north-western districts in India such conditions for ripening of date are available. During March to June, the heat unit summations at Jodhpur, Bikaner, Ganganagar, Barmer, Jaisalmer and Bhuj add up to 5,000, 5,040, 4,900, 4,690, 4,520 and 4,440 respectively (Pareek, 1977).

The home of date is in the Mediterranean region with practically no summer rain when its fruit matures. There is no location in India which meets this requirement but fairly dry conditions are available in north-western India. Early introductions of date-palm at Abohar, having an annual rainfall of 260 mm, mostly during July to September, have met with problems of fruit spoilage by cracking and splitting although possibility of good production of dates up to *doka* stage of maturity for fresh market and processing have been demonstrated.

Experience at Jodhpur, under 360 mm rainfall has been better due to lower humidity and faster berry maturity, reaching even early *dang* stage (softening from tip to full fruit) before the monsoon begins (Vashishtha and Pareek, 1978). Also rain damage is less. In fact, more than its quantum, the pattern and conditions under which rain occurs will make all the difference in the build up of atmospheric humidity and consequently in the extent of fruit spoilage. A light shower followed by prolonged cloudy weather will cause more damage than heavy rain followed by clear weather and drying winds. A light shower at late stage of fruit maturity will cause more damage than heavy rain during the early stage. Further westwards, Jaisalmer is still drier (178 mm rainfall) where test plantations have given fruits up to full *dang* stage of maturity. In Kachchh region, where monsoon sets in early, fruit cannot be retained on the tree beyond *doka* stage without spoilage.

Protection from rain damage is done in California and Arizona by ventilation of bunches and covering them with wax paper covers, open at the bottom (Tate and Hilgeman, 1962 ; Nixon, 1969). At Abohar, alkathene covers proved better than wax paper covers (Jawanda, 1974).

25.5 Propagation

Date-palm can be propagated by seed or by offshoots. Seedlings have a longer juvenile phase, and flower only when 4–10 years in age and result in nearly half

female palms which bear fruit of variable quality. Propagation of commercial variety is, therefore, always done by offshoots. After 3 to 5 years of attachment to the parent palm, the offshoots produce roots and start producing a second generation of offshoots, they are then ready to be removed (Nixon, 1969). At Abohar, after 4-6 years of planting about 2-3 offshoots could be removed every year for a period of 8-10 years and none thereafter (Bakhshi and Dhillon, 1962). At Jodhpur, offshoots could be separated 4-5 years of planting (Pareek and Muthana, 1978). A single palm may thus yield 10-25 offshoots during its first 10-15 years of life.

To promote rooting, the base of the offshoot should be in contact with moist soil for at least a year prior to separation. It can be done by mounding or by putting soil boxes on the offshoots arising high on the trunk. The per cent success of establishment largely depends on the size of offshoots, presence of roots on them, their preparation before separation and planting, season of separation and planting, etc. Toutain (1966) found that the success generally increased with increase in the weight of offshoots from 3-25 kg. Nixon (1969) recommended that the weight of offshoots ready for separation should range from 19 to 45 kg having 20-35 cm maximum diameter depending upon variety, and it would be safer to leave an offshoot a little longer on the parent palm than to remove it before it is mature and well rooted. Tate and Hilgeman (1962) recommended that the offshoots should be separated when 25-30 cm in diameter and 15-32 kg in weight. At Abohar (Jawanda and Kalra, 1972), offshoots of medium weight range (12-16 kg) proved better than those in the low weight range (8-12 kg).

Small offshoots can be induced to root by the application of IBA before removal from the mother palm and then putting them under mist (Reuveni *et al*, 1972).

Date-palm plantlets have been initiated from clonal explants via callus by culturing in a modified Murashige and Skoog medium and have been successfully transplanted from *in vitro* to free living conditions (Tisseret, 1981) but the application of the technique for large-scale multiplication is yet to be done.

25.6 Cultivation

Planting

In California, the best time to remove and transplant offshoots is after the soil begins to warm up in the late spring and early summer (Nixon, 1969). At Arizona, offshoots removed and planted during May and June had fewer casualties and made better growth than those planted in the late summer, fall or winter (Tate and Hilgeman, 1962). Spring planting took full advantage of the summer

growth period. At Abohar, the offshoots removed in March-April survived better in direct field planting than those removed in August-September (Bakhshi, 1972). However, the separation could be done both in February-March and August-September.

The offshoots are cut from the parent palm by means of a specially designed chisel. No green leaves should be removed from an offshoot until it is cut from the parent palm as its growth will be in proportion to its leaf area (Nixon, 1969). After the removal of offshoots, old leaf stubs and lower leaves are cut-off close to fibre, the basal 60–120 cm of offshoots being left bare of leaves so that the youngest 10–12 leaves around the bud are retained. (Tate and Hilgeman, 1962; Nixon, 1969).

Planting distance depends upon the variety, texture and fertility of soil and the means of irrigation. The offshoots are planted 9 m apart in Coachella Valley and in Arizona (Tate and Hilgeman, 1962; Nixon, 1969) and 5-8 m apart in Arab countries and in India. In Gujarat, the palms are planted 3–4 m apart.

Irrigation

The date-palm is drought resistant and is able to survive for long periods without irrigation. Drought, however, retards the growth. If available, date-palm uses water lavishly. It is highly tolerant to excessive irrigation and floods but permanent water logging is injurious. To maintain maximum growth, the root zone up to 2–3 m should be kept moist and not allowed to dry.

Immediately after planting, light and frequent irrigation must be given. Mulching may be useful at this stage. In sandy soils, irrigation may have to be given every day or on alternate days. The frequency of irrigation is reduced after the offshoots have established which will depend upon soil texture and weather conditions. In California, bearing gardens are usually irrigated every 7–14 days during mid-summer and every 20–30 days during winter (Nixon, 1969). In a dry soil, 2–3 irrigations totalling 8–12 acre inches in rapid succession should be given and thereafter 4–6 acre inches per irrigation may be sufficient.

It has been estimated that 4–5 acre feet of water is required to grow palms where the soil is dry during ripening and 6–8 acre feet will be required where heavy irrigations are continued throughout the year (Tate and Hilgeman, 1962). Experience in Coachella Valley indicated that on light soils not less than 9–12 acre feet of water per year is necessary for palms in full production and that from 12–18 acre inches per month is required during the summer (Nixon, 1969).

Water is usually applied in furrows or in basins. Trickle irrigation was found to give significantly higher yield than sprinkler irrigation (Reuveni, 1971).

Date-palm is also tolerant to saline irrigation water, but under such conditions its growth is retarded. Furr and Ream (1968) found that the

growth of Medjool and Deglet Noor seedlings with 3,000-24,000 ppm salt (mostly chlorides) was nearly linear with increasing salinity and there was 60 per cent growth reduction with 12,000 ppm salt.

Manuring and fertilisation

Fertiliser application is, particularly, important in light soils having poor fertility. In the Middle East and North Africa, animal manures have been used largely. In California and Arizona, barn-yard-manure is applied at the rate of 12·5–37·5 tonnes per ha in the late fall or winter (Nixon, 1969). Inorganic nitrogen is also applied in California date gardens. Studies have indicated that 1·8-2·7 kg of nitrogen per palm from all sources is adequate (Nixon and Carpenter, 1978). In variety Ahmar, a dose of 600 gm N, 100 gm P_2O_5 and 700 gm K_2O per palm had the best effect on growth and productivity (Lossois, 1971). In India, application of an annual dose of 50–60 kg farm-yard-manure or 1–2 kg ammonium sulphate per bearing tree in equal halves, one in January-February and the other in August-September has been recommended (Bajwa and Bakhshi, 1961).

Green manuring with leguminous cover crops in young palms up to 12-15 years age has given good results in the USA. Roderbourg (1970) found that the uptake of applied phosphorus was greater in palms with a cover crop of lucerne. Phosphorus application at the rate of 226·8 kg per ha of triple super-phosphate to the cover crop may be indirectly beneficial to the palm (Nixon, 1969).

Intercropping

In date orchards, intercropping can be done with advantage, especially during the first few years. Pulses like lentil, gram, peas, etc., and different types of vegetables can be cultivated provided there is no shortage of water.

Leaf removal

The bearing capacity of the palm is in proportion to the number of green leaves that it carries. Insufficient number of leaves results in low quality fruit and fewer inflorescences in the following spring. Tate and Hilgeman (1962) recommended that about 100 leaves per palm are required to maintain maximum fruiting. Since about 20 leaves are produced in a year, no leaf removal is required for 5 years. Stoler (1971) found that the number of clusters to be retained is one to every 7 or 8 leaves for varieties Khadrawy, Zahidi, Barhee, Hayani and Amri and one for every 8 or 9 leaves for Halawy, Deglet Noor and Dayri. Most of the Egyptian date-palm varieties exhibit alternate bearing. The total number of functional leaves that could be maintained on Zaghloul palm is around

75 leaves, while on a Hayani palm only about 50 leaves could be maintained. Leaf pruning in June gave better results than in February, (Hassaballa *et al*, 1982).

Older leaves which are surplus than the required number are pruned as they are less efficient in producing sugars. The pruning is done in June so that the bunches will be better ventilated during July and early August when most of the spoilage occurs. The spines from the leaves around the bunches are, also cut during spring to facilitate pollination.

25.7 Pollination, Fruit set and Fruit thinning

Pollination

Cross-pollination is the rule in date palm due to its dioecious nature. For natural pollination, equal number of male and female trees have to be grown together. In commercial plantation, mechanical or hand pollination is done. For this, 2–3 male trees are enough to polinate 100 female palms. When the female spathes crack open, 2–3 strands of male flowers are inserted between its strands. Thus, the flowering in polleniser palm must coincide with that in the female palm. If the male spathes open much earlier than female spathes, the pollen is dried and stored for use at a later date. Dried pollen containing about 10 per cent moisture can be stored satisfactorily with calcium chloride at room temperature for 2–3 weeks (Stoler, 1971). It can be stored until the next season in a refrigerator at about 4–5°C (Nixon, 1969). Dried pollen is used either by dusting it or putting 2 or 3 cotton pieces embedded in pollen in the female cluster.

The spathes generally emerge during February-March in north-western India and the flower opening starts during March-April. Receptivity of flower in some date varieties decreases rapidly after spathe splitting while in others a good set can be obtained even 7–12 days afterwards (Stoler 1971). Nixon (1969) recommened that pollination must be carried out during the first 2–3 days after the spathes open.

In date-palm, selection of good polleniser is important because the pollen affects the size of the fruit and the time of ripening. Various manifestations of metaxenia have been reported by Stoler (1971). The pollination of Deglet Noor with Fard 4 pollen appreciably shortened the ripening period of fruit (Lakhowa, 1966). Identification of good pollenisers is, therefore, of a great significance under Indian climatic conditions to advance ripening of fruits so as to avoid rain damage.

Fruit set

Fruit set is closely related to the percentage of viable pollen and temperature conditions during pollination. In Coachella Valley, good set was obtained when daily maximum temperature was in the range of 23·9–26·7°C or higher

(Brown *et al*, 1969). Poor-set resulting from low temparature may be improved by placing paper bags over the flower clusters at the time of pollination (Stoler, 1971). A fruit set of 50–80 per cent is considered sufficient for a full crop.

Fruit thinning

Fruit thinning is necessary to ensure adequate flowering in the following year, to improve the quality of fruit, to prevent delayed ripening and to reduce compactness of the bunches. Thinning can be done manually or by chemical sprays. Manual method is common in which removal of some bunches or removal of some strands from each bunch or shortening the length of the strands is done.

The amount of fruit that a palm can safely carry depends on the variety, age, size, vigour of the palm and the number of green leaves on it. Under normal growth conditions, 1–2 bunches in the fourth year and 3–4 bunches in the fifth year may be left (Nixon, 1969). Small, defective and broken bunches are removed in any case. Bunch removal should not be done later than 10 weeks after pollination (Miremadi, 1970).

Bunch thinning either by the removal of strands or shortening of the strands or by a combination of the two depends upon the variety and other conditions. The best method of thinning is by removing the inner strands of each cluster as the outer strands have larger berries. However, generally a combination of strand removal and strand shortening is used. In long-stranded varieties like Deglet Noor, the tips of all strands are cut to remove about one-third number of flowers or fruits leaving 20–35 berries and about one-third to one-half number of strands are removed (leaving 30–50 strands) from the centre of the bunch (Nixon, 1969). In short-stranded varieties like Halawy and Khadrawy, cutting back tips of strands to remove about one-tenth to one-sixth of total number of flowers or fruits, and removing about half or more of the strands from the centre of the bunch are considered satisfactory. The desirable number of fruits to be left is between 1,300 and 1,600 per palm, depending on the variety, (Stoler, 1971). The percentage thinning recommended is 40–50 for Khadrawy, 50–55 for Halawy, 50–60 for Zahidi and Barhee and 30 for Dayri while in Deglet Noor shortening the strands by one-third along with fruit thinning by 25–30 per cent was recommended by Stoler (1971).

25.8 Fruit growth and Development

Shabana *et al*, (1981) reported that in Sayer and Zahidi, fruit growth followed a sigmoid curve and had five stages, viz, *hababouk*, *chimri*, *khalal*, *rutab* and *tamar*. The *hababouk* stage starting soon after fertilisation is characterised by loss of two unfertilised carpels. The *chimri* stage, termed as depressed period, began 4 weeks after fruit set and lasted for 9 weeks and had two substages, rapid period of growth followed by slow increase in fruit weight. The *khalal* stage lasted

for 4–5 weeks and had slow increase in fruit weight. During *rutab* stage, the fruit started losing weight first slowly and then rapidly for about 4 weeks, continuing for about one week in the next *tamar* stage. Thus in the *tamar* stage, fresh weight of fruit became 9·9 gm and 9·1 gm respectively in Zahidi and Sayer.

In India, the four developmental stages are called *gandora* (hard green), *doka* (full grown, hard, yellow or red), *dang* (softening from tips to full fruit), *pind* (fully ripened and dehydrated). These stages respectively correspond to *chimri*, *khalal*, *rutab* and *tamar* of the Arabs. The fruit becomes edible from *doka* stage onwards.

In the Middle East, North Africa and USA, most of the harvest is done at *tamar* stage when the fruit has 60 to 84 per cent sugar, depending upon location and variety.

During ripening of reducing sugar varieties, inversion of sucrose is rapid and apparently complete while in sucrose type dates, it is slower and is often arrested resulting in proportionately higher contents of sucrose in the ripe fruits (Rygg, 1956). Sugar accumulation continues to a significant degree even after the fruit is fully softened. The fruits have a certain amount of astringency, depending on variety, up to the *doka* stage which is progressively lost with the loss of colour and moisture. The process of ripening is related with the enzyme activity in the fruit. In Deglet Noor dates, the onset and development of the activity of cellulase, polygalacturonase and invertase were found to be correlated with the fruit ripening (Hasegawa *et al*, 1972). The fruit quality depends on the hydrolytic enzyme activity. A deficiency of invertase results in the formation of sugar wall dates. Too low activity of enzymes causes an absence of process of cell wall degeneration and low sugar contents resulting in firm dates (Coggins and Knapp, 1969).

Used of growth substances

Plant growth substances have been found to influence the maturity and quality of fruit. Treatment of unpollinated bunches with 50 ppm GA_3 gave a high percentage of seedless fruit while treatment of pollinated bunches resulted in large size fruits (Ketchi, 1967). Treatment of date fruits with 400 ppm GA_3 increased fruit size and delayed ripening while Ethephon at 2,000 ppm decreased fruit size and hastened ripening and a combined treatment resulted in larger fruits which ripened early (Marel and Bondok, 1974).

25.9 Pests and Diseases

Pests

In India, no serious insects pests or diseases confront date cultivation.

In the north-western India, insect pest like termite in young date plantation and thrips (*Adihetrothrip jambudvipae*), scale insects, rhinoceros beetle

(*Oryctes rhinoceros*) and Indian palm weevil (*Rhynchophorus ferrugineus*) in bearing trees have been observed to cause some damage. Stored dates are attacked by cigar hoeing beetle (*Lasioderma testaceum*).

In Kachchh, black headed caterpillar (*Nephantis serinopa*) causes serious damage while red palm weevil and rhinoceros beetle have also been observed. The black headed caterpillars feed on the leaves hiding inside the tunnels in the folds of the leaves. It can be controlled by injecting 5-10 ml Monocrotophos in each palm through the roots. The red palm weevil grubs enter the palm near the ground and bore into the trunk upwards. To control the weevil 5% BHC should be dusted around the trunk. Clean cultivation is also very useful. If the grubs have already entered the trunk, fumigation should be done and the holes should then be plugged.

Birds are a great menace when the date berries start ripening. At Jodhpur, the effective way of protection was the use of wire cages as the other type of covers built up humidity around the bunches and caused fruit spoilage.

Diseases

The most common disease is false smut or *Graphiola* leaf spot caused by *Graphiola phoenicus* which attacks the leaves forming numerous dark brown or black pustules full of yellow spores, particularly under humid conditions. The infection causes early death of leaves. Bordeaux sprays have been found to keep the disease under check. Fruit rot caused by various fungi occur in humid weather and in poorly ventilated clusters.

25.10 Yield

The yield per palm, depending on age and type, in the seedling plantation in Kachchh varies between 50 and 300 kg. At Abohar, Halawy and Barhee have given 50–100 kg *doka* fruit and Khadrawy and Shamran have produced 40–70 kg fruit per palm. The yield from Medjool palm is up to 50 kg but its fruits are very large in size.

In California, the yield per palm varies from 45-55 kg in Khadrawy to 91–136 kg in Deglet Noor, Zahidi and Barhee (Nixon, 1969).

25.11 Artificial Ripening and Curing

Artificial ripening has to be done if the fruit is harvested before it is completely ripened which is usually done under unfavourable weather conditions. Two general types of fruits are produced by the process : (i) soft flesh date containing 35–42 per cent moisture, and (ii) dehydrated soft or semi-soft date containing

25–28 per cent moisture. Ripening can be done in maturation rooms kept at 35 to 54 °C with some provision of humidity control (Tate and Hilgeman, 1962). Higher temperature and humidity are required for less mature fruit having *doka* colour. Higher temperatures, however, result in darker product. Nixon (1969) recommended that Deglet Noor fruits picked when *doka* colour has disappeared should not be exposed to over 35 °C.

Tate and Hilgeman (1962) have given a maturation guide for fruits harvested from *dang* stage onwards. The fruits picked when one-third transluscent, are kept at 35–40 °C for 72–96 hours and dehydrated. Full transluscent fruits are kept at 40–46 °C for 48–72 hours and may require hydration or dehydration. The fruits picked when dry and shrivelled, would usually require hydration at 47–56 °C at 90 per cent relative humidity for one to two days. Dehydration of the fruit can be done either in an electric vacuum drying oven by maintaining the fruit temperature between 40 and 42 °C or in a solar dryer with a metal bottom and glass top.

Since the prospective date growing regions of India do not have completely rainless period from June to September, tree ripe fruits may not always be possible. Thus, harvest has to be done usually at *doka* stage during June-August when the fruit has 70–80 per cent water.

The fruits at *doka* stage have poor keeping quality and have either to be consumed immediately or must be cured or processed. In Iraq, *doka* fruits are boiled and then dried to make *chhuhara.* At Jodhpur, boiling for 20 minutes followed by dehydration was found to be the best to prepare *chhuhara* from Halawy fruits giving a recovery percentage of 40. At Abohar, *doka* fruits of Medjool were cured by dipping in boiling water for 10 minutes and those of Zahidi and Khadrawy for 5 minutes followed by dehydration in an air circulating oven at 49 °C to prepare *chhuhara.* Reasonably good quality of *pind khajoor* has also been prepared at Abohar by dipping *doka* fruits of Zahidi in boiling water for 20–30 seconds and then dehydrating in oven at 39 °C. Besides, the *doka* fruits can also be processed to prepare ready-to-serve drink. For this, the fruit juice is standardised to 14 per cent TSS and 0·3 per cent acidity by adding sugar and citric acid.

25.12 Breeding and Varietal Improvement

All commercial date-palm varieties have arisen by selection of chance seedlings based on local needs. Systematic breeding work has been started, comparatively, recently.

Carpenter and Ream (1967) have stated that the primary goal of date breeding is to achieve the highest fruit quality and yield consistent with local requirements which may include tolerance to adverse growing conditions and disease

and insect pests, modification in growth habit and fruit quality, suitability for various products, development of uniform inbred lines and male palms having useful metaxenic characters.

In the USA, date-palm breeding was started in 1948 with primary objective of producing female clones adapted to mechanical harvesting and processing, equal or better in quality than fruit of Deglet Noor which is subject to blacknose disorder, and slower in vertical growth than in this variety (Carpenter, 1979). Although 9 promising selections from 710 females out of a progeny from 52 crosses were made, none proved a suitable replacement to Deglet Noor. These selections are from the progenies of the crosses Deglet Beida × Dayri BC_2*, Empress × Khadrawy BC_3*, Horra × Dayri BC_2, Medjool × Tadela BC_1*, Medjool × (Dayri × Deglet Noor) F_1, Thoory × Deglet Noor BC_4*, Thoory × Khadrawy BC_3, Thoory × Halawy BC_3 and Thoory × (Dayri × Deglet Noor) F_1. Among soft varieties, the main objective is to combine the quality and yield of Medjool with long fruit stalks to facilitate handling of bunches (Carpenter and Ream, 1976).

Breeding for resistance to fusariose or bayoud disease caused by *Fusarium oxysporum* f. sp. *albedinis* is a major objective in Morocco. After 14 years of observations on 32 varieties Saaidi *et al*, (1981) found Bou Sthammi Noire, Iklane, Tadment, Sair-Layalet and Bou Feggous Ou Moussa to be completely resistant. Crosses between selected female parents, having either high quality dates or resistance to bayoud and the back-crossed varietal male palms developed in the USA, are being made. This is followed by screening of the resultant progenies against the disease by artificial inoculations. A number of selections have been made. In this programme, endeavour is made to link bayoud resistance characteristic of some selected seedling palms with the highest fruit quality and yield characters of the known commercial varieties (Djerbi, 1982).

No breeding work has so far been done on date-palm in India except evaluation of varieties against rain damage and selection of some promising female seedlings from the Kachchh groves. At Abohar, Zahidi variety has been found to be resistant to rain damage. Barhee is more tolerant than Shamran (Kalra and Jawanda, 1973). Gupta (1980) found Medjool to be resistant to rain damage as it missed rains owing to late fruit ripening. The main objectives of breeding under the Indian agro-climate should, however, be to develop an early maturing and dwarf variety resistant to damage by rain and high humidity, besides resistance to *Graphiola* disease.

The genetic behaviour of *P. dactylifera* is little known. Nixon and Furr (1965) found a significant resemblance to female parents, in vegetative and fruit characters, of progenies of some date varieties. Progeny of third back-cross of Barhee included many females having characters closely resembling those of the female

* BC_1, BC_2, BC_3 and BC_4 are respectively first, second, third and fourth generation back-crossed males.

parent. Varietal similarity also existed among the fruit of back-crossed progeny in Medjool and Khadrawy. This was not found to be so true in Deglet Noor.

Interspecific crosses of *P. dactylifera* with *P. sylvestris*, *P. reclinata*, *P. canariensis*, *P. roebelenii*, *P. rupicola* and *P. humilis* are successful and have metaxenic effects (Carpenter and Ream, 1976). This offers scope for improvement through breeding and selection of promising males. There is, however, ample scope of selecting or breeding for promising males within *P. dactylifera*. Even inter-generic crosses with pollen of coconut, giving 7–47 per cent fruit-set, and of *Oreodoxa regia*, giving 37–52 per cent fruit-set, have been successful (Mohamed and Mougheith, 1974). Interspecific and inter-generic hybridisation can be used for including moderate to slow vertical growth in date-palm.

Varietal improvement in *P. dactylifera* by breeding poses problems mainly due to dioecious nature and long life cycle of the palms besides the heterozygosity. Nixon and Furr (1965) used the tendency of resemblance in vegetative and fruit characters in developing varietal males which could be used in hybridisation programme. This was done by repeated back-crossing of the female parent of known variety with the resultant male progeny. The problems posed by long life cycle can be overcome by vegetative propagation *in vitro* (Oudejans, 1976). Tisseret and Torres (1979) have coded isozymes by seven genes with 14 alleles and have genotyped 45 female and 20 male date-palm varieties to provide single-gene markers to faciliate the hybridisation programme.

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26

JAMUN

P. N. Bajpai and O. P. Chaturvedi

The jamun (*Syzygium cumini* Skeels.) is an important indigenous minor fruit of commercial value. It is known as black plum, Indian black cherry, and also as *Ra Jamun*, *Kalajam*, *Jam* and *Phalinda* in different parts of India. The jamun tree is tall and handsome evergreen, generally grown for shade and windbreak on roads and avenues.

26.1 Composition and Uses

Jamun fruit possesses considerable nutritive value. It is a good source of iron, apart from the usual contents, e.g., minerals, sugars, protein and others. The nutritive value of this fruit as analysed by Nutrition Research Institute, Coonoor, is given in the Table below (Singh *et al*, 1967).

TABLE 1. NUTRITIVE VALUE OF JAMUN FRUITS

Moisture	28·2 per cent	Carbohydrates	19·7 per cent
Protein	0·7 per cent	Calcium	0·02 per cent
Fat	0·1 per cent	Phosphorus	0·01 per cent
Mineral matter	0·4 per cent	Iron	1·0 per cent
Fibre	0·9 per cent	Calorific value	83 per 100 gm

The biochemical changes during growth and development of jamun fruit, have been reported by Shukla and Prasad (1980). Mazumdar (1979) analysed fruits of *Syzygium jambos* and *S. malaccensis*.

The tasty and pleasantly flavoured jamun fruit is mostly used for dessert purposes and it is very much liked by the people. The fruit is usually shaken with salt before eating. The jamun fruit has sub-acid spicy flavour. Apart from eating afresh it can also be used for making delicious beverages, jellies, jam, squash, wine, vinegar and pickles (Ochse *et al*, 1961). Jamun squash is a very refreshing

drink in the summer season. A little quantity of fruit syrup is much useful for curing diarrhoea. A mixture of jamun juice and mango juice in equal quantity is very good for quenching thirst for diabetic patient. Jamun fruit is used for preparation of wine, particularly in Goa. The vinegar prepared from juice extracted from slightly unripe fruit is stomachic, carminative and diuretic, apart from having cooling and digestive properties (Thaper, 1958).

Almost every part of the tree is used for one purpose or the other. A tea prepared from tender leaves and alcoholic extracts of leaves and fruits are used in South America for curing the stomach disorder. Powdered seeds are also very useful for the cure of diabetes. The seed powder of jamun reduces the quantity of sugar in the urine very quickly and permanently. It is used as a lotion for the cure of ringworm (Quisumbing, 1951 ; Dastur, 1952).

Jamun seed can be used as a concentrate for animals because it is rich in protein, carbohydrates, and calcium (Thaper, 1958). Its wood is used for railway sleepers. It is not attacked by wood decaying insects or fungi. The jamun seeds were exported from India to Malaysia, Polynesia and from West Indies to Europe and England for typical medicinal uses (Benthall, 1946 ; Wren, 1956).

26.2 Origin and Distribution

The original home of jamun is India or the East Indies (Singh, 1969). It is also found in Thailand, Philippines, Madagascar and some other countries. The jamun has been successfully introduced into many other tropical countries like West Indies and East and West Africa and also some other subtropical regions including Florida, California, Algeria and Israel (Popenoe, 1920 ; Morton, 1963-64).

In India, the maximum number of jamun trees are found scattered throughout the tropical and subtropical regions. It also occurs in the lower range of the Himalayas up to an elevation of 1,300 metres and in the Kumaon hills up to 1,600 metres. It is widely grown in the larger parts of India from the Indo-Gangetic plains in the North to Tamil Nadu in the South (Chaturvedi, 1956 ; Singh *et al*, 1967). It is one of the most hardy fruit crop and can be easily grown in neglected and marshy areas where other fruit plants can not be grown successfully.

26.3 Species and Varieties

Species

The genus *Eugenia* comprises about 1,000 species of evergreen trees and shrubs, most of which are tropical in origin. Some of the Old World *Eugenia* spp. are now placed in the genus *Syzygium*. It belongs to the family Myrtaceae.

Many of the species yield edible fruits and some of these are of ornamental and medicinal value. A wild species, *S. fruiticosum*, with small edible fruit is grown as windbreak. The large evergreen tree has small dark purple fruit with prominent elongated seed. The fruit is astringent even when ripe. A popular fruit, is the rose-apple or *gulab jamun* (*S. jambos*). It is found in South India and West Bengal, the tree is very ornamental. The fruit is yellow in oolour, generally insipid in taste and has high pectin content. *S. zeylanica*, a small tree with edible fruits, is found on the Western Ghats of India (Naik, 1963) and *S. malaccensis* (Malay rose-apple), a few trees of which are found in South India. Another related fruit found in South India is the 'Surinam cherry' or 'Pitanga cherry' (*S. uniflora*). It is a small tree with bright red fruit having an aromatic flavour. The other species *S. javanicum* (water-apple) is also found in South India and West Bengal. *Syzygium densiflora* is used as root-stock in jamun and it is resistant against the attack of termites.

Varieties

There are no named or standard varieties of this fruit under cultivation. The common variety grown under North Indian condition is 'Ra Jamun'. It produces big-sized (length 2·5–3·5 cm and diameter 1·5–2·0 cm), oblong fruit, deep purple or bluish black in colour at full ripe stage. The pulp colour of ripe fruit is purple pink and the fruit is juicy and sweet. The stone is small in size. This variety ripens in the month of June-July and it is very common in both rural and urban markets.

Another late maturing variety bears a small sized (length 1·5 2·0 cm and diameter 1–1·5 cm), slightly round fruit, deep purple or blackish in colour at full ripe stage. The colour of the pulp is purple, less in juice, weight and sweetness of pulp in comparison to that of 'Ra Jamun'. The stone present in this variety is comparatively large in size. Fruits ripen in the month of August.

At present, there are a number of seedling strains of jamun in India which provide a good scope for selection of better varieties. While selecting a variety the following points should be kept in mind.

Oval or oblong shape of fruit, deep purple or bluish black colour, big size, more pulp, small stone, juiciness, sweetness and earliness.

26.4 Soil and Climate

Soil

The jamun tree requires deep loam and well-drained soil for its optimum growth and good fruiting. Its cultivation should be avoided in very heavy or light sandy soils.

Climate

Jamun is successfully grown under tropical and subtropical climate. It requires dry atmosphere at the time of flowering and fruiting. Early rains are beneficial for proper growth, development and ripening of fruits. The young plants are susceptible to cold and drought conditions.

26.5 Area and Production

Information regarding the area of this fruit in India is not available because it is seldom planted in the form of an orchard and generally scattered trees are found in fruit plantations. They are also seen growing in parks, on road sides, avenues and as windbreak.

26.6 Propagation

The most common method of jamun propagation is by seed. Seedling plant bears fruits of variable size and quality. Such trees are generally hardy and long-lived. For improved and selected true-to-type plants, vegetative methods of propagation, like inarching, budding, cutting and air-layering have been advocated.

Seed

Jamun seeds sown fresh usually show a high percentage of germination within two or three weeks (Mowry *et al*, 1941), but if stored they lose their viability rapidly (Shanmugavelu, 1967). Shanmugavelu (1970) also reported that treatment with GA_3 improved the seed germination and seedling growth.

In North India, fresh seeds are sown 4–10 cm deep at a distance of 25 × 15 cm. The seedlings become ready for transplanting in the next monsoon, i.e., July-August.

There is occurrence of polyembryony in jamun (Tiwari, 1926) and the use of apomictic seedlings can be exploited. The percentage of polyembryonic seeds varies from 20–50 (Singh and Thakur, 1977).

Vegetative propagation

Inarching

The rootstock used for propagating jamun is the jamun seedling. For raising the rootstock, seeds are collected from healthy, vigorously growing and high yielding jamun trees. Seedlings are raised either in bed or in pots singly. In the month of June-July one or two-year-old rootstocks are inarched with the matching thickness of scion. Rootstocks are watered, if necessary till the grafts are separated from the parent tree. The time taken for union is about six weeks.

Veneer grafting

Saha (1970) recorded 31 per cent success in veneer grafting when one-year-old seedlings were used as rootstock. The shoots were taken from spring flush and the operation was done in the month of July.

Budding

Budding is generally employed for propagating jamun in Indonesia. It is an advantageous method of propagation over inarching because of the difficulty in finding suitable scion shoots in jamun near the ground. This method also reduces the expenditure in comparison to inarching. One-year-old, 10–12 mm thick root-stocks budded in July-August showed better success (Singh *et al*, 1967). The scion wood or bud wood is taken from one to two-year-old vigorously growing shoots. In India, shield, patch and Forkert methods of budding are generally employed. Singh *et al*, (1979) at Basti, Uttar Pradesh noted 70 per cent success by patch budding in the month of March. Forkert method was better than shield or T-budding (Singh *et al*, 1967).

The old, unproductive trees or damaged young plants can be rejuvenated easily by topworking, employing scion wood or buds from superior clone.

Cutting

Gupta and Chattopadhaya (1954) failed to obtain any rooting response with cuttings from June to January. Shanmugavelu (1966) reported 45 per cent rooting with 100 ppm IBA and 40 per cent with 100 ppm IAA treatments. Bose and Sadhu (1974) observed that tip cuttings *Syzygium javanicum* rooted well under intermittent mist and treatment with IBA at 5,000 ppm produced 100 per cent rooting. Sadhu and Naskar (1975) reported that girdling of shoots of *S. javanicum* greatly increased the rooting.

Air-layering

At Annamalai (Andhra Pradesh), all the air-layered shoots treated with IBA and NAA in lanolin paste at 0·1 per cent rooted whereas untreated layers failed to root (Shanmugavelu, 1967). Singh (1968) from Shaharanpur, Uttar Pradesh reported 86 per cent rooting when white polythene film and 1 per cent IBA in lanolin paste were used in air-layering of jamun. Saha (1970) found that 60 per cent of the air-layers rooted when treated with 500 ppm IBA, provided air-layering was done in spring and not in the rainy season.

26.7 Cultivation

Planting

Jamun can be transplanted both in spring, i.e., February-March or monsoon, i.e., July-August, the best time being July-August, because the plants easily get established during the rainy season. The plants are transplanted with the soil ball

intact, and are given irrigation till they get established. Jamun plants can be conveniently planted at a distance of 10–12 metres in square system in pits (1 × 1 × 1 metre) dug during May-June and filled with a mixture of surface soil and well-rotten farm-yard-manure.

Pruning and training

Regular pruning in jamun plant is not required ; however, in later years the dry twigs and crossed branches are removed. While training the plant, the framework of branches is allowed to develop above 60–100 cm from the ground level.

Irrigation

In the early age, the plants require 8-10 irrigations in a year while full grown (bearing) trees require 4–6 irrigations during the month of May and June, when fruits ripen. In other part of the year, irrigation may be given when there are no rains and soil is dry. Irrigation in winter months helps to protect the plants from frost injury.

Manuring and fertilisation

A full dose of 20 kg well rotten farm-yard-manure during the pre-bearing period of jamun tree and at bearing stage 80 kg FYM per tree should be supplied annually for proper growth and fruiting. Sometimes in a highly fertile soils, the plants produce profuse vegetative growth and fruiting is delayed. When such tendency occurs, the manure or fertiliser should not be given and irrigation should also be given sparingly and withheld in September-October and again in February-March. This procedure will prove beneficial in fruit bud formation, flowering and fruit setting. Ringing and root pruning are also helpful.

Intercropping

Intercropping of jamun orchard with suitable crop not only brings good income but also improves fertility of the soil. Fruit crops like peach, guava, kagzi lime, as fillers and field crops like gram, peas, mung, urid, etc., can be grown successfully. In addition, intercrops of vegetables near established market may be taken with cauliflower, cabbage, knol-khol, radish, brinjal, turnip, carrot and others.

26.8 Flowering, Pollination and Fruit set

The inflorescence in jamun is generally borne in the axils of leaves on branchlet. The flowering starts in the first week of March and continues up to the

end of April. The trees are in full bloom in the second week of April. The flowers are hermaphrodite, light yellow in colour. The maximum anthesis (18·71 to 43·08%) and dehiscence were recorded between 10 a.m. and 12·0 noon. The pollen fertility was higher in the beginning of the season. The maximum receptivity of stigma was observed one day after anthesis (Misra and Bajpai, 1975).

The jamun is a cross-pollinated crop. The pollination is done by honeybees, houseflies and wind. The maximum fruit-set (32·6 to 36·0%) was obtained when pollination was done one day after anthesis. Thereafter, a sharp decline was observed in fruit-set (Misra and Bajpai, 1975).

Flower and fruit drop

Misra and Bajpai (1971) observed that the flower and fruit drop in jamun start just after opening of flowers and continue up to maturity. There is about 65 per cent flower and fruit drop in the first five weeks and since then a maximum of 19–21 per cent flowers and fruits drop off up to maturity. Only 12–15 per cent flowers reach maturity. The flower and fruit drop are found at three stages.

(i) The first drop takes place during bloom or shortly thereafter, and this proves to be the heaviest drop as about 52 per cent of the flowers drop off after 4 weeks from flowering.

(ii) The second drop starts after about 35–40 days of full bloom and apparently there is no difference between the developing and aborting fruits.

(iii) The third drop takes place after 42–50 days of full bloom and continues till 15th July.

The extent of flower and fruit drop in jamun may be reduced by two sprays of 60 ppm GA_3, one at full bloom and the other 15 days after initial setting of fruit (Misra and Bajpai, 1971).

26.9 Fruit Growth and Development

Shukla (1979) recorded three distinct phases of fruit growth, viz., during the first phase, the rate of growth was slow (15–52 days after fruit-set), in the second phase (52–58 days after fruit-set), the rate of development was quite rapid and the third and last phase (58–60 days) comprised comparatively slow growth with little addition of the fruit weight.

26.10 Pests and Diseases

Pests

Leaf eating caterpillar (*Carea subtilis*) : In South India, at Coimbatore it is reported to damage the plant (Anantanarayanan and Vanugopal, 1952, 1954, 1955). The insect infests the leaves and may defoliate the trees. Treatment with Rogor, Malathion has proved effective.

White fly (*Dialeurodes eugeniae*) : It damages the tree in all parts of India (Singh, 1949). Sometime the fruits of jamun get wormy due to attack of fruitfly (Thaper, 1958). It can be controlled by maintaining sanitary situation in the orchard, which consists in picking up the affected fruits and burying them deep in soil and the area under the tree should be dug, so that the maggots in the affected fruits and the pupae hibernating in the soil may be destroyed.

The jamun fruits are also damaged by squirrels, and birds such as parrots and crows. For keeping them away, beating of drum or flinging small dry earthen balls through a sling is useful.

Diseases

Glomerella cingulata causes leafspots and fruit rot. Affected leaf shows scattered spots light brown or reddish brown in colour. The affected fruits rot and shrivel. It may be controlled with fungicide like Diathane Z-78 at 0·02 per cent or Bordeaux mixture (4 : 4 : 50).

26.11 Harvesting

The seedling jamun plants start bearing after 8–10 years of planting while grafted ones after 6–7 years. The fruit ripens in the month of June–July. The main characteristic of ripe fruit at full size is deep purple or black colour. The jamun fruit should be picked immediately when it is ripe, because it can not be retained on the tree in ripe stage. The ripe fruits are picked singly by hand and in all cases care should be taken to avoid all possible damage to fruits. For harvesting, the picker climbs the tree, with bags of cotton slung on the shoulder. When the bag is full, the picker comes down from the tree and empties the bag in baskets or with the help of rope, hangs the bag down to the ground and another person standing below the tree, catches the bag and empties it in baskets. The fruits of jamun is generally harvested daily and sent to market on the same day. The jamun fruit is highly perishable and can be kept in good condition for about 2–3 days under ordinary conditions.

26.12 Yield

The average yield of fruit from a full grown seedling jamun tree is about 80–100 kg and from a grafted one 60–70 kg per year.

26.13 Storage

Shukla (1979) observed that the storage life of jamun fruit is 6 days at room temperature and 3 weeks at low temperature (9°$\pm$1 °C and RH 85–90%) when pre-cooled fruits are kept in perforated polythene bags.

26.14 Breeding and Varietal Improvemet

In West Bengal, Percy Lancaster and Bose (1965) noted that F_1 hybrid of a cross between the Alba variety from water apple (*S. javanicum*) and the rose-apple (*S. jambos*) possesses prolific fruiting habit but the fruits are seeded and larger than those of either parent, have the fragrance and sweetness of the rose apple. Two or three flushes of flower come every year, but in first flowering the maximum number of fruit is obtained. This hybrid is easily propagated by air-layering and gives large number of fruit in the third year of planting.

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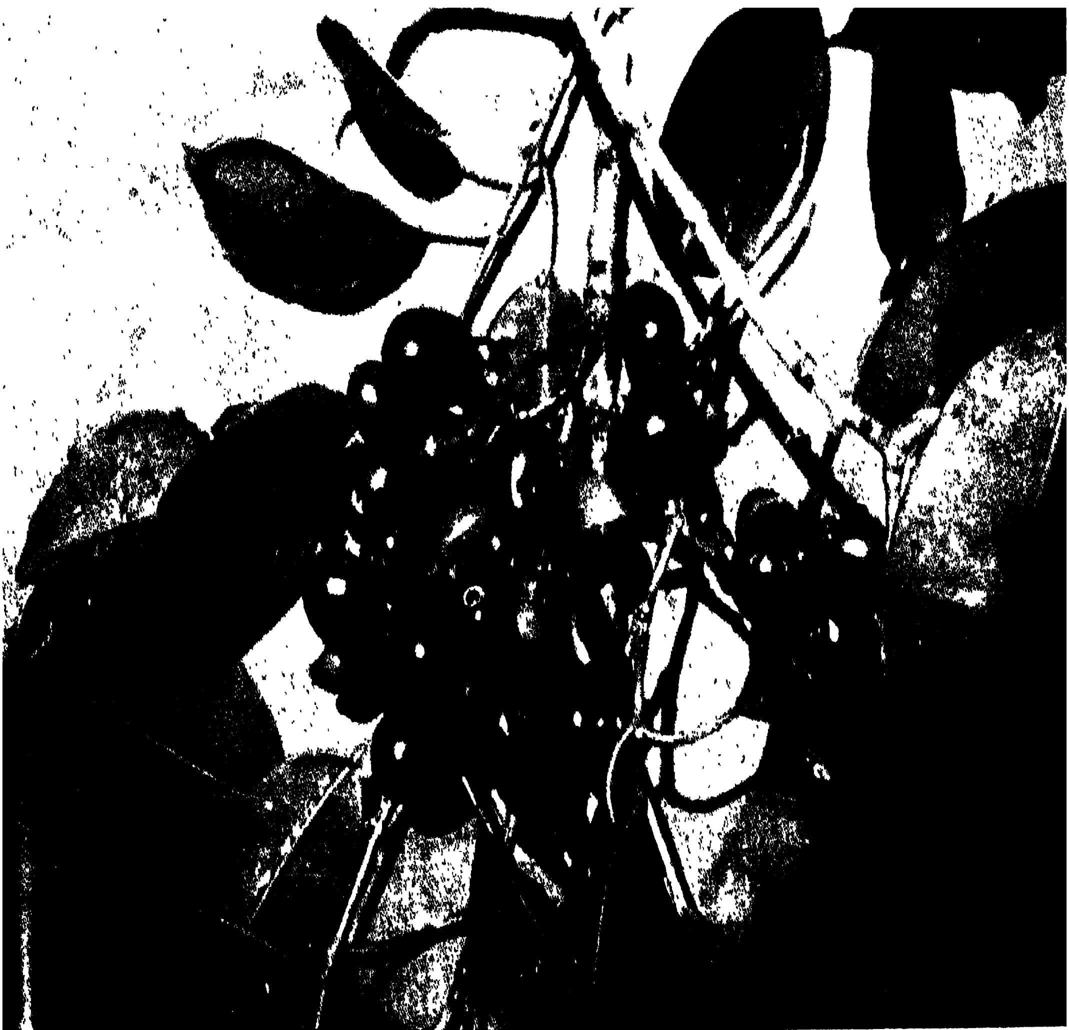

Clusters of jamun

Aonla in bearing

27

AONLA

P. N. BAJPAI and H. S. SHUKLA

The aonla (*Emblica officinalis* Gaertn. syn. *Phyllanthus emblica* L.), one of the most important minor fruits and a crop of commercial significance, is quite hardy, prolific bearer and highly remunerative even without much care. It belongs to the family Euphorbiaceae and is known as *amla, amlaki, amali, ambala, amalakamu* and *nelli* in different parts of India.

27.1 Composition and Uses

The fruit is highly nutritive (Table 1) and it is the richest source of vitamin C among fruits except Barbados cherry (Asenjo, 1953). The fruits are made into preserves (*murabba*), sauce, candy, dried chips, tablets, jellies, pickles, tophies, powder, etc. The ascorbic acid and other constituents are well retained in dried aonla fruits (Srivastava and Srivastava, 1964). The variations in ascorbic acid content have been recorded by various workers (Table 2). The aonla powder is superior to synthetic vitamin C in treating deficiencies. The stability of ascorbic acid and presence of astringency in aonla fruit may be assigned to the presence of polyphenols or leucoanthocyanins (Sastry *et al*, 1956). Hanif *et al*, (1966) noted marked antioxidant effect of gallic acid present in aonla fruit.

It is valued as an antiscorbutic, diuretic, laxative, alterative, (Nadkarni, 1927) and antibiotic (Ray and Majumdar, 1976). One or other part of the plant could be used in treating chronic dysentry (Chopra *et al*, 1958), bronchitis, diabetes, fever (Drury, 1873), diarrhoea (Dalzell and Gibson, 1861), jaundice, dyspepsia, cough (Burkill, 1935) and in tanning and dyeing industries. The literature regarding its diverse medicinal, industrial and other applications has been nicely reviewed (Anon., 1952 ; Morton, 1960). The properties and nature of inhibitors of potato virus x in plant extract (Verma *et al*, 1969), pharmacological activities of phyllemblin isolated from fruit pulp (Rao and Siddiqui, 1964) and protective effects of fruit extract in myocardial necrosis (Tariq *et al*, 1977) have been reported.

TABLE 1. COMPOSITION OF AONLA FRUITS

Moisture	81·2 per cent	Phosphorus	0·02 per cent
Protein	0·5 per cent	Iron	1·2 per cent
Fat (ether extraction)	0·1 per cent	Calorific value	59/100 gm
Mineral matter	0·7 per cent	Vitamin/B_1	30 mg/100 gm
Fibre	3·4 per cent	Nicotinic acid	0·2 mg/100 gm
Carbohydrates	14·0 per cent	Vitamin C	600 mg/100 gm
Calcium	0·05 per cent		

TABLE 2. VARIATION IN ASCORBIC ACID CONTENT OF AONLA FRUITS

Ascorbic acid content (mg/100 gm)	Reference
540-720	Srinivasan (1944)
588·0	Naik *et al*, (1951)
1561·1-1814·0	Mustard (1952)
900·07 (large fruits)	Janaki Amal and
872·3 (small fruits)	Raghavan (1957)
747·0	Jain and Lal (1954)
450·0-665·0	Teaotia *et al*, (1968)
563·3	Bajpai (1969-71 a)

27.2 Origin and Distribution

Aonla is said to be indigenous to tropical south-eastern Asia, particularly in central and southern India (Firminger, 1947). It is also reported to be the native of India, Ceylon, Malaysia and China, thrives well throughout tropical India and is met with wild or cultivated in the region extending from the base of the Himalaya to Ceylon and from Malacca to South China. The tree is also common in the mixed deciduous forests of India ascending to 1,350 metres on the hills (Anon., 1952).

27.3 Species and Varieties

Species

The genus *Phyllanthus* (Greek for leaf flower) comprises about 350 (Hooker, 1973) or even 500 species (Bailey, 1917), mostly shrubs, some herbs or trees. Recently, with the revision of the genus, *Phyllanthus emblica* Linn. has been placed under *Emblica* as *Emblica officinalis* Gaertn (Anon., 1969) There are other species which are also used for pickling, etc., as *Phyllanthus acidus* Skeels. popularly known as Otaheite gooseberry, star gooseberry, or country gooseberry ; *Emblica fischeri* Gamble (syn. *Phyllanthus fischeri*) and *Phyllanthus longiflorus* Heyne.

Perry (1943) reported the somatic number of chromosome in aonla to be $2n=28$ while a variation from $2n=98$ to 104 has been observed by Janaki Amal and Raghavan (1957).

Varieties

There has been no standardisation of varieties of aonla and they are mostly known on the basis of size (Janaki Amal and Raghavan, 1957), colour (Singh, 1967) or after the names of places. The varieties mainly classified according to their colour are Green-tinged, Red-tinged, Pink-tinged, White-streaked, and Bansi Red. Singh (1974) reported that important varieties grown in the district of Pratapgarh (Uttar Pradesh) are Banarasi, Chakaiya and Pink-tinged, which can be grown successfully under North Indian conditions. Teaotia *et al*, (1968) described the physico-chemical characteristics of some aonla varieties.

Banarasi variety has its origin from Varanasi and is known as the best variety of aonla. Fruits are fairly large, shiny yellowish, and very good for making preserves ; fruit quality fine, early bearer and keeping quality good.

Chakaiya is a very hardy variety ; regular and heavy bearer ; fruit quality medium, bearing mid season, keeping quality very good.

Hathijhool is believed to have its origin in Pratapgarh district (Uttar Pradesh) ; heavy bearer, fruit quality good, bearing late, keeping quality poor.

Deshi is very hardy but bears smaller fruits, poor in quality, heavy and late bearer.

There are other varieties, viz., Francis, Pratapgarh fibreless, Bansi Red, etc., which can be popularised.

The variations in the chemical composition of fruits of different aonla varieties are given in Table 3 (Teaotia *et al*, 1968).

TABLE 3 CHEMICAL COMPOSITION OF FRUITS OF AONLA VARIETIES

Varieties	Percentage					Vitamin C in mg/100 gm pulp	Seed/pulp ratio
	TSS	Acidity	Total sugar	Reducing sugars	Non-reducing sugars		
Banarasi	13·0	2·34	8·0	1·045	6·607	625·21	1 : 21
Hathijhool	11·5	2·52	7·0	4·085	3·054	584·00	1 : 22
Chakaiya	9·0	2·17	9·6	1·995	7·225	645·00	1 : 17
Bansi Red	15·0	2·32	8·2	1·382	6·477	665·00	1 : 17
Deshi	15·2	2·58	7·1	1·035	5·761	450·00	1 : 15

27.4 Soil and Climate

Soil

Aonla can be grown in light as well as heavy soils except very sandy one. However, well-drained fertile loamy soil is the best. The plants have capacity for adaptation to dry regions and can also grow in moderately alkaline soils.

Climate

Aonla is a subtropical fruit but its cultivation in tropical climate is quite successful. The tree is not much influenced either by hot wind or frost; however, older plants have been found damaged with frost (Gangwar *et al*, 1975). The young plants should be protected from hot wind (loo) during May-June and from frost during winter, at least up to the age of 3/4 years under North Indian conditions. The mature plants can tolerate freezing temperature as well as a temperature as high as 46°C (Shanker, 1969). The warm season appears conducive for the initiation of floral buds (Bajpai, 1963).

27.5 Area Production

Data regarding area under aonla cultivation are not available. Although, it is found growing in different states throughout tropical India even up to elevations of 1,500 metres in South India (Singh, 1979), it is more popular in Uttar Pradesh where it is largely cultivated in commercial orchard in Azamgarh, Pratapgarh, Varanasi and Bareilly districts. In view of its diverse uses, its cultivation is increasing fast and the tree is becoming popular with the orchardists. Since aonla is quite hardy, it should occupy a larger area in the dry regions of the country.

27.6 Propagation

Seed

The aonla plants have long been raised from seeds but the plants do not come true-to-type and produces small sized fruits, inferior in quality. Seedlings are raised from seeds and used as root stock. Bajpai (1969-71b) reported that the seeds attain full maturity by February when they should be extracted and sown in the last week for getting high percentage of germination. Bhujbal (1975) obtained the highest percentage of germination (92·5) and the best root system with stones soaked in 500 ppm GA_3 for 24 hours.

Vegetative propagation

In order to overcome the disadvantages of seed propagation, multiplication of superior types in aonla has been suggested by adopting vegetative methods (Hayes, 1957; Singh, 1967; Srivastava, 1964, 1965; Gangwar *et al*, 1975; Amin, 1978). Of the various methods of vegetative propagation, budding has been found to be most practical and shield budding is the commercial method of aonla propagation under North Indian conditions (Singh, 1974). Singh (1952) reported that one-year-old aonla seedlings with a girth of about one centimetre should be shield budded in early June with healthy and plump buds from new growth.

Shield budding gave a success of 70-81.1 per cent (Singh, 1967 ; Gangwar *et al*, 1975). However, even higher percentage of bud-take was recorded with Forkert and patch methods (Srivastava, 1964, 1965 ; Moti *et al*, 1976). Amin (1978) recorded 70 per cent success following soft wood grafting at the site of the terminal shoot of the rootstock raised *in situ* for a year or more. It would be advisable to raise seedling rootstocks *in situ* and bud them with superior types, particularly in dry areas where mortality of budded plants is usually high.

The most important factor is the proper selection of mother plant which is highly fruitful and the buds should be taken from such a branch which has good number of female flowers, otherwise the plants will be unfruitful owing to the appearance of a large number of male flowers.

Top working

Older trees of inferior type can be rejuvenated and easily changed into superior type by resorting top working. Singh (1953) reported that inferior trees can be headed back to a height of 1·2 metres from the ground during March and the stumps produced can be shield budded in early June with scions of improved varieties. Frost damaged older aonla plants were also rejuvenated by T-budding (Gangwar *et al*, 1975).

27.7 Cultivation

Planting

Prior to the planting, the field should be deeply ploughed, harrowed and levelled. The pits, about 1 metre cube should be dug during May-June at appropriate distance and after 15-20 days of exposure to the sun, are filled with surface soil mixed with 10-15 kg of decomposed farm-yard-manure. If depressions take place in the pits with the onset of rain, more soil should be added. Healthy, grafts or budded plants are planted during rainy season, preferably during the early monsoon in July with square system at a distance of 9 metres (Singh, 1967) or 11 metres (Singh, 1974) each way. In dry areas where mortality after transplanting is usually high, the seedling root stocks can be raised *in situ* at appropriate distance for budding superior clone.

Training and pruning

As the branches of aonla trees often break off carrying heavy crop load due to brittle nature of wood, the plant should be trained to develop a low headed one and the main branches constituting the foundation framework should be made to arise on the trunk within 0·75 metre from the ground. The plant should be trained to modified leader system. The framework should be developed by encouraging the growth of four to six well spaced branches with fairly wide angle.

The pruning of the bearing plants can be done after the termination of the crop each year. While pruning, dead, diseased, broken, weak, crossing branches and suckers appearing from rootstock should be removed.

Irrigation

Aonla plants hardly require any irrigation during rainy season except long spell of dry period. The young plants require watering during summer months at fortnightly interval, particularly till they have fully established. Watering of mature, bearing plants is also necessary from April to June at bi-weekly interval to secure higher fruit set and reduced fruit drop. Irrigation during October to December at 20 days' interval helps in better development of fruits.

Manuring and fertilisation

Very little is known about the manuring and fertilisation of aonla as no schedule based on experiments has so far appeared. Singh (1967) observed that each tree should be given 3-4 kg superphosphate. Shanker (1969) suggested the following schedule though not based on any investigational evidence. The young plant should be given 15-20 kg of well rotten farm-yard-manure and the mature tree 30-40 kg each year during September-October. In addition, application of 30 gm nitrogen for each year age of the plant up to 10 years and afterwards 680-900 gm of nitrogen/plant/year should be provided. Every mature tree should also be fertilised with 1 kg superphosphate and 1-1·5 kg muriate of potash. The above fertilisers should be given in two equal split doses to mature bearing tree, once during September-October and again during April-May after setting of fruit. The plants need to be irrigated after fertiliser application.

As regards nutritional status, Garg and Khanduja (1976) observed that leaf analysis for N, P, K, Na, Ca and Mg of plants raised in normal and alkaline soils revealed N and P to be most affected by soil pH. The nutrient assimilation capacity was adversely affected most in aonla and least in ber.

Intercropping

It is better to follow clean culture in aonla plantation except during the rains when leguminous crops, viz., moong, cowpea, urid, etc., can be grown up to 8 years when the plants usually remain in non-bearing stage and their root system and top growth are not much developed.

27.8 Flowering, Pollination and Fruit-set

Flowering

Bajpai (1965) noticed flower bud differentiation in Banarasi aonla in the first week of March. The development of male and female gametophyte was normal.

The flowers commence opening from the last week of March and the blooming period lasts for 3 weeks. Male flowers appear in clusters in the axil of leaf all over the branchlet while female flowers on the upper end of a few branchlets only (Bajpai, 1957). Bajpai (1968) reported sex ratio (male to female) to be 307·9 : 1 and 197 : 1 as recorded in the year 1960 and 1961 respectively. The maximum number of male flowers open between 6 and 7 p.m. and dehiscence of anthers occurs soon or about 10-15 minutes after anthesis. The female flowers open in stages and it takes 72 hours to open completely and the stigma becomes receptive on the third day of anthesis.

Fig. 1. Showing flower on a branchlet.

Fig. 2. Showing female flowers at the top and male flowers at the bottom.

Pollination and fruit set

It is wind pollinated as the pollen grains are light and are produced in abundance. Although actual fertilisation could not be traced, zygote was observed within 24 to 36 hours of pollination (Bajpai, 1968).

There is no self-incompatibility in aonla and the cause of poor fruit-set (12·18-18·33 per cent) may be due to a high percentage of staminate flowers (Bajpai, 1968). An increase in fruit set under hand pollination (18·00-27·74 per cent) indicates the need of pollinating agents for better setting.

Flower and fruit drop

Bajpai (1968) recorded flower and fruit drop at three stages. The 'first drop' is heaviest as 70 per cent of the flowers drop off within three weeks of flowering

due to degeneration of the egg apparatus and lack of pollination. The 'second drop' occurs from June to September due to lack of pollination and fertilisation. The 'third drop' consists of fruits of various stages beginning from third week of August until October probably due to embryological and physiological factors.

27.9 Fruit Growth and Development

After the fruits have set, the embryo lies in dormant condition and ovary does not exhibit any symptom of external growth until middle of August. The diameter and volume of the fruit increase rapidly thereafter, and the maximum growth is achieved by November after which there is not much increase in size. The growth of the fruit is due to the enlargement of the cells of the mesocarp while endocarp cells form the hard stone cells (Bajpai, 1968). Anatomical changes in developing aonla fruits have also been reported by Bajpai (1969-71b).

Growth substances in aonla fruit

Ram and Rao (1976) reported 6 cytokinin-like substances in aonla fruits showing growth after dormancy. They did not find any association of cytokinin deficiency with dormancy of the fruits. Further studies on naturally occurring gibberellins in aonla fruits indicated negligible gibberellin activity during dormant stage while higher activity was linked with higher rate of fruit growth and in the rapidly growing fruits 6 gibberellin-like factors were identified, five of which behaved like gibberellin A_1, A_3, A_4, A_7 and A_9 (Ram and Rao, 1978).

27.10 Pests and Diseases and Physiological Disorder

Pests

Bark eating caterpillar (*Inderbela* sp.) : It makes tunnel in the main trunk or branches. The pest can be controlled by spraying 0·03 per cent Endrin or injecting kerosene oil or petrol in the holes and plugging them with cotton or wet soil during September-October and February-March.

Shoot gall maker (*Betousa stylophora*) : The young caterpillars bore into shoots and reach the pith during August-September. The damaged region develop into a gall like formation. Pruning of the affected parts and spraying of 2 per cent parathion have been suggested to kill the larvae.

Diseases

Aonla rust : It is caused by *Ravenellia emblicae*. At Saharanpur, Deshi variety was found severely affected while Banarasi and Chakaiya were free from

it (Nirwan *et al*, 1969-71). Brown pustules are formed both on leaves and fruits and finally these pustules become dark brown. Spraying with Dithane Z-78 at 0·2 per cent proves effective.

Blue mold: It is caused by *Penicillium islandicum* (Setty, 1959). Brown patches with water soaked areas are formed and the fruit is ultimately covered with bluish-green pustules. Control by storage hygiene and treatment of fruits with weak borax or sodium chloride solution have been suggested.

Chahal and Singh (1969) also isolated *Penicillium oxalicum* and *Aspergillus niger* from rotting aonla fruits.

Physiological disorder

Ram *et al*, (1976) reported internal fruit necrosis, a disorder associated with boron content in aonla fruits, at Pantnagar (Nainital). It could be controlled with three sprays of borax at 0·6 per cent at fortnightly interval, commencing from early September.

27.11 Harvesting

Aonla plants start bearing quite late, usually after 8 to 10 years. The fruits are light green at first, but when they mature, the colour becomes dull, greenish-yellow, or rarely brick-red (Naik, 1949). Bajpai (1969-71a) observed that the best time of harvesting aonla fruits is February when the fruits have maximum vitamin C content. If the fruits are allowed to remain on the tree till the next flowering takes place, it gives a false impression that these fruits are from the current season flowering. In South India, fruits are found throughout the year at some places.

The mature fruits are hard and unyielding to the touch and so are well suited for bulk harvesting as well as distant transportation and marketing. For getting attractive price, fruits after harvest should be made into different grades depending on the size.

27.12 Yield

A full grown grafted aonla tree with good bearing habit yields from 187 to 299 kg fruits per year (Singh, 1967). Yield records at Allahabad showed a yield of 1·8 and 1·6 quintals from a 10 year-old tree of Chakaiya and Banarasi varieties respectively. Singh (1974) reported that average fruit yield is 200 kg per grafted tree.

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28

POST-HARVEST HANDLING OF FRESH FRUITS

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Post-harvest loss of fresh fruits is one of the most pressing problems of the tropical countries like India. A huge quantity of highly nutritious fruits go waste due to lack of proper post-harvest handling. The reduction of post-harvest losses is a complementary means for increasing production. It may not be necessary to considerably step up the production of fruit crops with the growing demand if the post-harvest losses are reduced to a great extent. The cost of preventing losses after harvest in general is less than producing a similar additional amount of fruit crop of the same quality. Attention to the concept of post-harvest food loss reduction as a significant means to increase food availability was drawn by the World Food Conference held in Rome in 1974. Proper post-harvest handling of fresh fruits will prevent seasonal market glut, supply a wide selection of fruits round the year, help in orderly marketing, preserve the quality of fruit, provide sufficient surplus for export and better return to the growers.

28.1 Physiological and Biochemical Aspects

The quality of the harvested fruits depends both on the condition of growth as well as the physiological and biochemical changes they undergo after harvest. Proper understanding of various post-harvest physiological and biochemical events is of great significance. Fruits after harvest lead an independent life as they are removed from the parent plants and the normal supply of water, minerals and other organic molecules are completely cut off. The harvested fruits do not have any significant photosynthetic process but they carry out all other physiological processes such as transpiration, respiration, ripening, etc. From the above, it is clear that regulation of the physiological and biochemical changes and control of microbial infection are of paramount importance in the post-harvest handling of fruits. These aspects have been discussed in this chapter.

Maturity

The post-harvest quality and storage life of fruits appear to be controlled by the maturity. If the fruits are harvested at a proper stage of maturity the quality of the fruit is excellent. Poor quality and uneven ripening are caused by early harvesting and late harvesting results in extremely poor shelf life. It is imperative that the fruits should be harvested at the right stage of maturity with no physical damage or bruise whatsoever. Sometimes, there is a confusion between maturity and ripening, a proper understanding of the two terms is necessary. Maturity can be described as the attainment of a particular size or stage after which ripening takes place. On the other hand, ripening means the qualitative changes in fruits after maturity, as a result of which it becomes edible. Various maturity indices such as number of days from fruit-set, visual indicators, size, shape, colour, appearance, texture, lenticel number, specific gravity, starch content, soluble solids, sugar : acid ratio and oil content are used to determine the maturity of fruits. Bhatnagar and Subramanyam (1971) reported that in mango vars. Alphonso and Piare it took 110 to 125 days after fruit-set for surface colour to change from dark green to olive green and flesh colour from white to pale yellow. It was noted that Biward mango required 15 weeks after fruit-set to attain mature green stage with maximum diameter 7·5 cm or over (Cancel *et al*, 1979). An interesting feature observed by Mann and Singh (1976) was the reduction of lenticels with the maturity of the fruit. Ruechle and Ledin (1955) noted that Haden mango was found to be immature at specific gravity less than 1·015, and ready for picking when the value was 1·02 or more. The general practice observed in this subcontinent is to harvest mango when a few ripe fruits fall naturally from the tree; this process is known as *tapka*. Roy and Pandey (1983) reported that at this stage 80 per cent fruits (var. Dashehari) were mature and had attained specific gravity above 1·00. It was also observed that fruits having specific gravity above 1·04 were partially ripe and below that were green at the time of harvest. Popenhoe *et al*, (1958) observed that the point of maximum starch content was found to be a reliable yardstick of maturity of Haden and Zill mangoes grown in Florida.

The maturity of pineapple is characterised by accelerated decline in shell pH and marked increase in flesh brix and titratable acidity (Gortner *et al*, 1967). Starch is usually absent in horticulturally mature orange fruits (Ting and Attaway, 1971). According to Sinclair and Joliffe (1958), in maturing orange there is a decrease in the total pectin and water soluble pectic substance in the peel and pulp. The stage of maturity of banana is determined by experience and judged largely by the visual appearance of the hanging bunch and particularly by the angularity of the individual banana fingers (Palmer, 1971).

Respiration

In the post-harvest life of the fruit, respiration plays a very significant role. Respiration has considerable bearing on whatever changes take place in the fruit

after harvest. It results in the biological oxidation of certain materials, particularly the simple sugars. During respiration the sugar disappears with the uptake of O_2 and production of CO_2 and H_2O. A great deal of energy is also liberated as heat at the time of respiration. The conversion of sugar and O_2 into CO_2 and water does not take place in one gigantic step but through a long series of reactions. The initial phase of respiration is production of pyruvic acid from glucose, a phase known as glycolysis. The terminal phase of respiration is the conversion of pyruvic acid into carbon dioxide and water, which is strictly aerobic. The pathway of pyruvic acid through the various organic acids to CO_2 and water is known as the citric acid cycle or Kreb's cycle.

When sugars are oxidised in respiration one molecule of CO_2 is evolved for each molecule of O_2 taken up during the process. The ratio of CO_2 evolved to O_2 consumed $\frac{CO_2}{O_2}$ is known as the respiratory quotient or R. Q. of the process. The concept of the respiratory quotient is useful because it gives us the idea of the substrate used for respiration. Sugars are by no means the only substrate for respiration. Organic acids, fats and other compounds may also contribute to respiration. The R. Q. for respiration of fats is less than 1 because they are poorer in oxygen and richer in hydrogen than sugars. The R. Q. for respiration of organic acid is greater than one as organic acids are richer in oxygen than sugar.

1. $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$; R. Q. = 1
   (Glucose)
2. $C_{18}H_{36}O_2 + 26O_2 = 18\,CO_2 + 18\,H_2O$; R. Q. = 0·7
   (Stearic acid)
3. $C_4H_6O_5 + 3\,O_2 = 4CO_2 + 3\,H_2O$; R. Q. = 1·33
   (Maleic acid)

In most of the fruits, the rate of respiration increases rapidly with ripening. The sudden upsurge in respiration is called the 'Climacteric rise', which is considered to be the turning point in the life of the fruit. After this, senescence and deterioration of the fruit begin. The fruits belonging to this type of respiratory process are called climacteric fruits. In non-climacteric fruits, there appears to be a simple gradual decline in respiration. According to Biale (1960) banana, papaya, mango, passion fruit, sapota, etc., are the major tropical fruits which belong to the climacteric group and pineapple, fig, grape, lemon, etc., belong to the non-climacteric group. Roy *et al*, (1972) and Roy and Singh (1980) reported that bael fruit (*Aegle marmelos*) belongs to the category of climacteric fruit.

The rate of respiration is a good index of the post-harvest life of fruit. To extend the post-harvest life of the fruit, its respiration rate should be reduced as far as possible. Once harvested, carbohydrates utilised through respiration

cannot be replaced and the calorific value of the fruit is reduced. An understanding of the factors which influence the rate of respiration is indispensable to post-harvest technologists for manipulating the storage behaviour of fruit.

Ripening

Ripening of fruits can take place while they are attached to the tree and/or after they are harvested, depending on the species of the fruit. With ripening, changes occur in colour, flavour and texture which render the fruit acceptable to the consumer. These quality changes are accompanied by respiratory changes in the fruit, which have been discussed earlier, and compositional changes such as transformation in pigments, pectins, carbohydrates, acids, phenolics, etc. Compositional changes in fruit during ripening are ideal if the fruits are harvested at the proper maturity. Immature fruits will have unsatisfactory quality. Colour change in fruit is due to degradation or breakdown of chlorophyll and consequence unmasking of carotenoid pigments in case of oranges. Fruit softening is caused by the breakdown of insoluble protopectin and formation of soluble pectin. During ripening there is decrease in starch and increase in fructose, glucose and sucrose resulting in sweetness of the fruit. Ripening also decreases the organic acids and phenolics to reduce the acidity and astringency and makes it more acceptable. An increase in volatile compounds to give the characteristic flavour of a fruit also takes place during ripening.

The most striking chemical changes which occur during the post-harvest ripening of banana are the hydrolysis of starch and the accumulation of sugar. About 20–25 per cent of the pulp of the fresh green fruit is starch and after ripening only 1–2 per cent remain in the fully ripe fruit. Sugars, normally 1–2 per cent in the pulp of green fruit, increase to 15–20 per cent at ripening. Total carbohydrate decreases by 2–5 per cent during ripening, presumably as sugars are utilised in respiration (Laesecke, 1950). The start of ripening in pineapple is indicated when there is a rapid loss of shell chlorophyll, the flesh pH and respiration rate reach a minimum and begin to rise, volatile esters accumulate rapidly, shell brix increases, flesh pigments increase rapidly while shell pigments decline, and titratable acid reaches a peak and begins to decline (Gortner *et al*, 1967).

Ethylene

Ethylene (C_2H_4) is known as the ripening hormone. Exogenous application of ethylene to promote ripening has been known for a long time (Cousins, 1910). The prevalent view is that ethylene is produced in sufficiently high concentration during the preclimacteric stage to induce the rise in respiration and ripening process (Burg and Burg, 1965). The amino acid methionine is the immediate potential precursor of ethylene production in fruit tissue. The conversion of

methionine to ethylene was demonstrated by Bour *et al*, (1971). Mature unripe fruits are stimulated to ripen if treated with very low concentration of ethylene gas of about 0·1 ppm. Ethylene is 100 times more effective than acetylene as a ripening agent (Pantastico and Mendoza, 1970). According to Mattoo *et al*, (1968) during the ripening of Alphonso mango ethylene gas evolved was in the range of 0·02 to 0·18 ppm.

There are various ethylene liberating compounds available which can control the ripening and senescence. Ethrel (2-Chloroethane phosponic acid) is one such chemical. Campbell and Malo (1969) reported that application of Ethrel shortened the ripening period and thereby reduced the incidence of anthracnose in mango. Application of Ethrel imparted attractive colour to mangoes and increased their commercial value but reduced the ascorbic acid content (Pandey and Singh, 1976). Ripening of mango by Ethrel was also reported by Chundawat *et al*, (1973). Advancement of ripening by application of Ethrel has also been observed in many fruits by various workers (Rom and Scott, 1971 ; Maxie *et al*, 1971). Bael fruit could be ripened ahead of schedule and made available in the off-season by the application of Ethrel coupled with storing at 30 °C (Roy *et al*, 1972 and Roy and Singh, 1981). According to Mann and Dhillon (1974), fruits ripened by calcium carbide had better palatability, attractive colour and superior quality attributes.

Citrus fruits are degreened with Ethephon which actually induces carotenoid synthesis, apart from hastening chlorophyll degradation (Daito and Hirose, 1970). Application of ethylene at 0·1 ppm or higher to green bananas accelerate the onset of the climacteric stage (Biale *et al*, 1954).

28.2 Harvesting and Field Handling

In most of the developing countries including India, manual harvesting is in vogue using ladders, poles, clippers, etc. A number of harvesting aids have been developed in some countries to eliminate the use of ladder, as for example mobile platforms which place the picker in the correct harvesting position. The large size of fruit tree poses a great problem in manual harvesting resulting in more damage to the fruits. However, with the concept of dwarfing the fruit trees and high density orcharding manual harvesting will become easier and more efficient.

Buckets, sacks, baskets and boxes are used to collect produce from the plant for transfer to a central collection point. Many of these containers are poorly designed, inadequately maintained and unsuitable for the job. The field containers should be designed in such a fashion that they do not cause any injury to the harvested fruits. During the harvesting and field operation a high standard of field hygiene should be maintained. Produce unfit for marketing should be removed. Under no circumstances should rejected produce be allowed to remain

on the ground for any extended period of time as it becomes a source of infection. Preferably, disease infected material should be destroyed. The time of harvest is one particular factor frequently neglected but which often affects product quality and shelf-life. As a general rule, there are advantages to be gained in harvesting produce during the cool part of the day in order that fruit temperature can be kept as low as possible during subsequent handling. This means early morning or late afternoon harvesting.

28.3 Packaging

Packaging of fresh fruits has a great significance in reducing the wastage. Packaging also provides protection from mechanical damage, undesirable physiological changes and pathological deterioration during storage, transportation and marketing. Supervision and sorting prior to packaging can eliminate the defects and provide a uniform quality of the fruits packed. A wide variety of containers such as wooden boxes, baskets woven from bamboo or twigs, hessian sack/jute bags, earthen pots and corrugated fibre board boxes are the important package forms used in the transportation and distribution of fruits in most of the developing countries. All the packages must have some amount of ventilation in order to prevent physiological breakdown. The commercial basket and sack/bag have poor dimensional stability as well as stacking strength, yet they are the prime packaging materials for fruits in India. The wooden box has disadvantages like heaviness which adds to freight costs ; however, it has positive advantages like good stacking strength. But extensive use of wooden boxes will deplete the forest wealth and bring an ecological imbalance. The corrugated fibre board boxes are comparatively new and making significant entry into the field. Wooden boxes consume two to three times as much wood as required for a similar size corrugated fibre board box. The kraft paper required for making corrugated fibre board boxes can easily be manufactured from bamboo, grass and various types of agricultural residues as well as by recycling the used cardboard or paper. Corrugated fibre board boxes have mostly substituted the wooden boxes in the advanced countries. These have many advantages : (i) are light in weight, (ii) cause much less damage to fruits, (iii) are easy to handle and print, (iv) improve the product image, (v) reduce the freight cost and finally (vi) can be prepared from cheaper wood and other plant cellulose waste. The most important constraint in the introduction of corrugated fibre board boxes is its high price. These corrugated fibre board boxes have great potentiality for export market.

28.4 Transportation

In order to maintain fruit quality and avoid heating, the fruit should be harvested and removed from the field as rapidly as possible. The fruits

once harvested should be protected from adverse weather conditions. Fast transport of fruit with minimum damage during shipment is very important in successful marketing of perishables. In India, the road transport is 3–4 times more expensive than the rail, moreover, rail shipment is 8–10 times more efficient in the use of energy than road haulage for the movement of the same tonnage, yet in India road transport is preferred for shipment of fresh fruits, simply because of the faster movement of perishable commodities and advantage of door-to-door service. The present system of hauling fruits in road trucks and railway wagons is highly defective and needs thorough improvement. Both the road trucks and railway wagons should have a special system of ventilation and arrangements to reduce the temperature and maintain proper relative humidity. This can be successfully done without using high cost mechanical refrigeration, simply by adopting the technique of evaporative cooling with a slight modification in the existing road trucks and railway wagons. The surface of the roads and their maintenance need improvement in order to have smooth transportation without vibration. The road transport can even be faster if all the national highways are made one way and unnecessary delay caused by the closure of the level crossing is prevented. This can be done by construction of flyovers instead of level crossing, particularly at the road-rail intersections on the National Highways. Efficient transport system can go a long way not only in reducing the post-harvest loss of horticultural produce but also in stabilising the price fluctuations of the same commodity available in different corners of the country.

28.5 Marketing

It is quite apparent that marketing plays a key role in the post-harvest operation of fruit. A perfect and efficient marketing system covers all aspects of handling from the stage of harvesting till the commodity reaches the consumer. Marketing of perishable fruits presents more problems compared to other durable agricultural commodities. It is not done properly in most of the developing countries. The interests of the producers as well as consumers are poorly served, the grower gets less return and consumer pays more than is necessary.

Due to the presence of the middleman the price of fruits is 60–100 per cent higher in *mandis* than in growing areas. The middlemen are also known to manipulate the situation by artificially creating gluts and offering low prices to the growers, falsely rejecting the produce as substandard and indulging in other malpractices. A strong financial backing through some efficient organisation is necessary to free producers from the dominance of traders. The cooperatives can play a very important role in the marketing of fresh fruits. The

importance of grading and quality control has been established in marketing, but there is a lack of positive research and development in the marketing system.

28.6 Storage Aspects

Storage is one of the most important aspects of the post-harvest handling of fruits. The main object of storage of fresh fruits is to extend their period of availability. A substantial quantity of fruits go waste in our country due to lack of proper storage facilities. It has already been stated that fruits and vegetables are living entities and they carry out all the vital physiological activities even after harvest. The primary purpose of storage is to control the rate of transpiration, respiration, ripening and also any undesirable biochemical changes and disease infection. The loss of many perishable fruits can be prevented to a great extent by controlling the post-harvest environmental conditions of temperature, relative humidity, atmospheric concentration of certain gases and also by chemical treatment and irradiation. There are various techniques and methods to increase the storage life of fruits which are discussed below.

Refrigeration

The principle of refrigeration is to take out heat. In mechanical refrigeration the refrigerated gas (e.g., ammonia, freon, etc.) takes out the heat from the chamber/store as it expands. The expanded gas is then compressed, the heat is removed from the compressed gas by means of running water or circulating air over the tubes containing the hot gas. The gas is liquefied and the cycle is then repeated. With such a system accurate temperature control is possible.

Cool store

In cool store, the temperature control is very important. The ideal environmental condition for fresh fruit in storage is the lowest temperature which does not cause chilling injury to the produce. Any variation from the desired condition is detrimental. Relative humidity of the storage rooms also has considerable bearing on the keeping quality of horticultural commodities. It is very difficult to control the moisture in air. A small temperature difference between the cooling coil and the stored fruits is required to maintain an adequate control of relative humidity in a storage room (Desrosier, 1970). In order to increase relative humidity, water may be sprayed into the controlled storage chamber. The storage life of fruits varies inversely with the rate of

respiration and evolution of heat. The ideal conditions for cool storage of some of the important tropical fruits are given below :

Fruit	Temperature °C	Relative humidity %	Storage life weeks
Banana	13	85-90	1-5
Bael fruit	9	85-90	10-12
Guava	8-10	85-90	2-5
Jack fruit	11-13	85-90	6
Litchi	2	85-90	8-12
Lime	11-13	85-90	8
Lemon	5-7	85-90	6
Mango	8-10	85-90	4
Papaya	8	85-90	2-3
Pineapple	8-10	85-90	1-2

Ice bank cooler

A recent development in refrigeration is the Ice Bank Cooling System with positive ventilation (Farrimond *et al*, 1979). The system positively directs the ice cool air through the boxes containing fresh fruit. As a result quicker cooling is possible and large amount of heat can be removed in a relatively short period of time. In this system, a bank of ice is built up with a relatively small refrigeration plant. The ice is accumulated on extended surface plates, which are suspended in a tank of water. The water surrounding the ice is pumped to the top of a cooling tower and falls through the tower passing over the extended surface, giving a large surface area of heat exchange. The air leaving the tower maintains high humidity. Once the initial cooling is complete the store maintains a temperature of 0·5–0·8 °C and relative humidity of 98 per cent.

Chilling injury

Chilling injury or low temperature breakdown is one of the major problems in storage of fresh fruits. The phenomenon of chilling injury is comparatively little understood. The chilling damage is essentially different from freezing damage, as it occurs in tissue exposed to temperature near, but above their freezing point and in some cases damage may be observed even at a temperature as high as 14 °C (Fidley and Coursey, 1969). This type of spoilage is more acute in tropical fruits. The chilling injury of fruits is responsible for great economic

losses during storage or even in prolonged refrigerated shipment. The symptoms of chilling injury of some tropical fruits are given below :

Commodity	Symptoms of chilling injury
Mango	Uneven ripening, dull and blemished skin, loss of sweetness.
Banana	Fails to ripen properly, increase in tannin content, hardening of central placenta, inhibition of starch/sugar conversion, reduced ascorbic acid content.
Lime and Lemon	Skin pilling, slow degreening, membrane discolouration, oil glands darker than surrounding areas.
Papaya	Fails to ripen properly, skin pitting, conversion of sucrose to reducing sugar inhibited.
Pineapple	Uneven ripening, discolouration of flesh, crown wilting, fails to develop ideal flavour.
Litchi	Skin colour becomes dull.

Controlled/modified atmosphere

The work on controlled atmosphere storage started in England after the First World War. Kidd and West (1927) regulated CO_2 and O_2 in a gas-tight storage chamber and termed it gas storage. The term was abandoned in the late 1940's because of its unpleasant connotations and became known as controlled atmosphere storage (Hall, 1968 and Smóck, 1979). Modified atmosphere does not differ in principle from controlled atmosphere storage, except that control of gas concentration is less precise. In this system the produce is held under atmospheric conditions modified by package, overwrap, boxliner or pallet cover (Lipton, 1975). The first requirement of controlled atmosphere is a sufficiently gas-tight envelope around the produce and the second requirement is some means of maintaining the concentration of CO_2 and O_2 at the desired level. This method in combination with refrigeration, markedly enhances the storage life of fruit. The fruit that has derived the most benefit from controlled atmosphere storage is the apple. Among the tropical fruits, the best atmosphere for storage of mangoes is 5 per cent CO_2 and 5 per cent O_2 at 13 °C (Spalding, 1977).

Controlled atmosphere storage improved the appearance of the pineapple fruit by reducing the superficial mould growth. The optimum O_2 level was 2 per cent. Levels of O_2 below that were ineffective in extending storage life (Akamine and Goo, 1971). Spalding and Reeder (1974) indicated slight benefit with papaya when the fruits were stored in 5 per cent CO_2 and 1 per cent O_2 for 3 weeks at 13 °C. Initiation of ripening can be delayed for weeks or months by holding the green banana fruits in an atmosphere of 1–10 per cent oxygen, 5–10 per cent CO_2 or combination of low O_2 and high CO_2 (Mapson and Robinson, 1966). In

general, the response of citrus fruits to CA has been disappointing. CA storage of Florida citrus is not recommended ; fruit decay from stem end rot is the limiting factor and in many cases it seems to be increased by high level of CO_2 (Chace, 1969). There is also a hazard of ethylene accumulation. According to Hatton and Cubbedge (1977) commercial CA recommendations cannot be given for citrus fruits.

Hypobaric (subatmospheric)

In hypobaric storage system the commodity is placed in a vacuum tight and refrigerated container and evacuated by a vacuum pump to the desired low pressure. The process of ripening and senescence are greatly retarded by decreasing respiration and evacuation of ethylene given out by the produce (Dilley, 1978). This is a very expensive method.

Waxing

The outer surface of fruits have a natural waxy layer which is partly removed during handling and washing. An extra discontinuous layer of wax applied artificially provides the necessary protection against decay organism. The practical benefit from wax coating is usually a reduction in evaporation and respiration. It has been reported that where refrigerated storage facilities are not available protective skin coating with wax is one of the methods developed for increasing the storage life of fresh fruits (Srivastava, 1962 and Dalal *et al*, 1971).

Polymeric film

The rapid development of semipermeable film and the growing use of this packaging material for pre-wrapping produce has led to consideration of the possibilities for establishing 'controlled atmosphere' produce package. A produce package is a dynamic system in which two main processes, respiration and permeation, are occurring simultaneously. There is an uptake of O_2 (oxygen) by the produce and evolution CO_2 (carbon dioxide), C_2H_4 (ethylene), H_2O (water) and other volatiles, and at the same time, specific restricted permeation of these gases through the packaging film (Hening, 1975). It has been found that polyethylene bags retarded respiration and transpiration and helped increased shelf life and retention of the quality of certain fruits (Salunkhe and Norton, 1960 and Salunkhe *et al*, 1962).

Chemicals

There are certain chemicals other than fungicides which increase the self life of fruit by delaying the ripening and senescence. Post-harvest treatment with

gibberelic acid markedly retards ripening of banana (Murata *et al*, 1965). Many chemical formulations have been tried to keep ethylene below the threshold level. Potassium permanganate (an ethylene absorbant) on vermiculite has been found to be a more practical material. A commercial preparation of this absorbant called 'Purafil' (alkaline potassium permanganate on a silicate carrier) proved effective in the complete absorption of ethylene from banana held in sealed polyethylene bags (Scott *et al*, 1968 and Lin, 1970).

The effect of maleic hydrazide on the ripening process varies with different fruits. Mangoes dipped in 1,000 and 2,000 ppm maleic hydrazide delayed ripening (Krishnamurthy and Subramanyam, 1970). It was found to hasten ripening of sapota (Lakshminaryana and Subramanyam, 1967). Foliar sprays of IPC (isopropyl-N-phenyl carbamate) reduced the rate of respiration, ripening and spoilage of sapota fruits during storage (Lakshminarayana *et al.*, 1967). Storage life of citrus fruits was prolonged by application of 2, 4-D and 2, 4, 5-T (Stewart *et al.*, 1952). There was less physiological loss in weight, less vitamin C loss and a high marketable percentage in stored 2, 4, 5-T treated Coorg mandarin oranges (Rodrigues and Subramanyam, 1966).

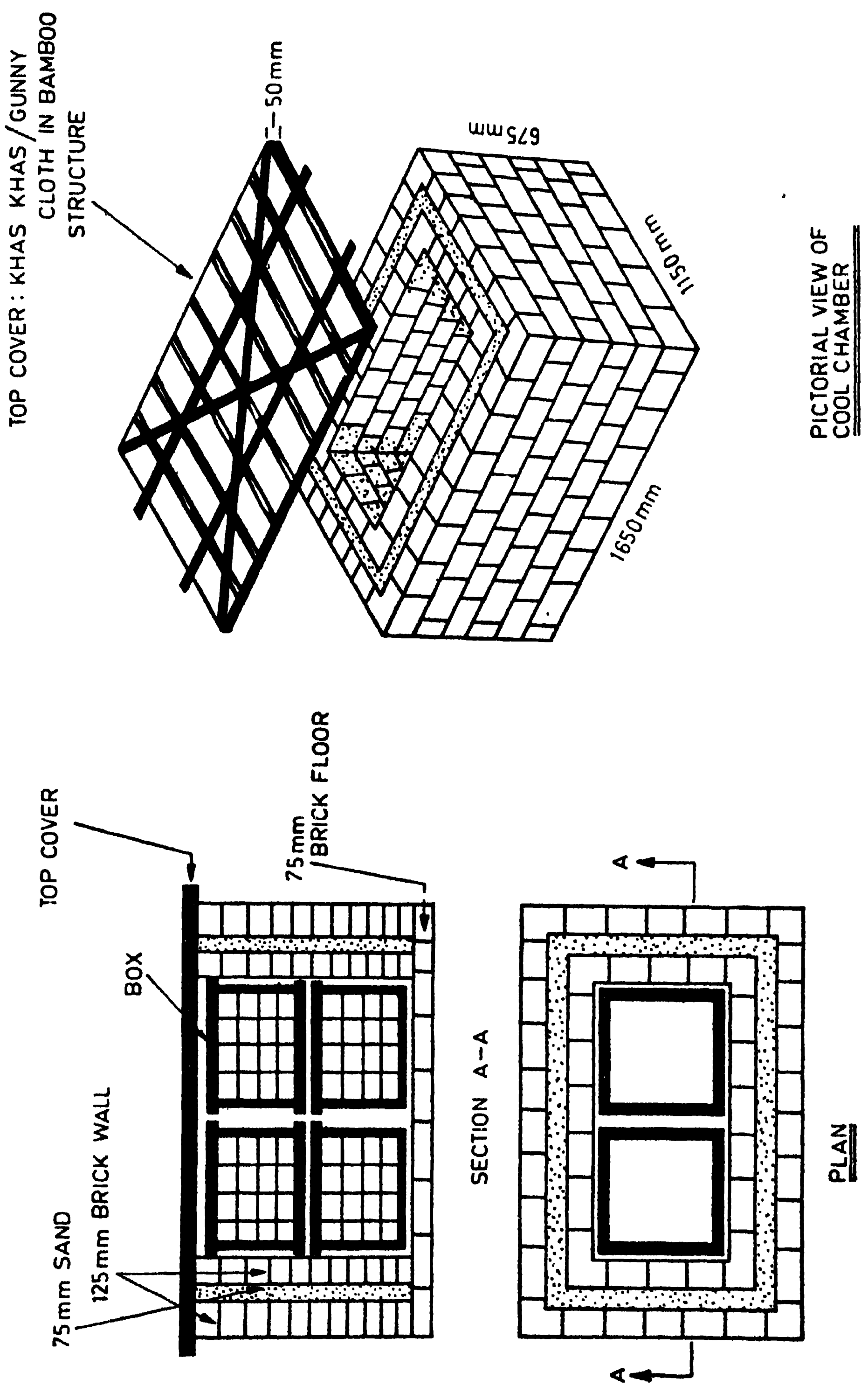
Irradiation

Considerable interest has been shown and many investigations have been conducted on the potential use of ionising radiation to extend the shelf life of perishables. Gamma radiation not only helps in destruction of the micro-organisms but also alters the physiology of fruits (Salunkhe, 1961). Studies have shown that the ripening of mangoes can be retarded by application of ionising radiation (Dharkar and Sreenivasan, 1968).

Irradiation with 25–35 K-rads is also reported to delay initiation of natural ripening of banana without interfering with ethylene induced ripening or affecting the quality of the fruit (Maxie and Sommer, 1968).

Evaporative cooling—cool chambers

Evaporative cooling is Nature's very own method. The ancient Egyptians used a primitive form of evaporative cooling, dating back to about 2500 B.C. and so did the Mughals a few centuries ago. Evaporation of water produces a considerable cooling effect and the faster the evaporation the greater is the cooling. Evaporative cooling occurs when air, that is not already saturated with water vapour, is blown across any wet surface. Thus evaporative coolers consist of a wet porous bed through which air is drawn and is cooled and humidified by evaporation of water. Theoretically, the lowest temperature, that can be reached by the evaporation of water is the wet bulb temperature (Hall, 1975). Evaporative cooling is widely used for comfort cooling of living and working spaces in hot, dry climates and it has a considerable potential for pre-cooling



TOP COVER : KHAS KHAS/GUNNY CLOTH IN BAMBOO STRUCTURE
50mm
675mm
1150mm
1650mm
PICTORIAL VIEW OF COOL CHAMBER
TOP COVER
75mm BRICK FLOOR
BOX
75mm SAND
125mm BRICK WALL
75mm
SECTION A-A
PLAN
A
A

Fig. 1

and even storage of fruits. The principles of evaporative cooling can be gainfully utilised for storage of fresh produce, particularly in rural India, as it can be constructed even in a remote village.

Based on the principles of evaporative cooling, low cost low energy input cool chambers have been developed (Roy and Khurdiya, 1982a and 1982b). The structures have been made from cheap, locally available raw materials such as brick, sand, bamboo, khas khas, gunny cloth, etc., with a source of water supply. The floor of the storage space is made with a single layer bricks, the side walls with a double layer of bricks, the space (7·5 cm) between the bricks being filled with river bed sand. The top of the storage space is covered with khas khas/gunny cloth in a bamboo structure (Fig. 1). Once the cool chambers are saturated with water, sprinkling of water once in the morning and once in the evening is enough to maintain the temperature and humidity. These cool chambers can reduce the temperature by 17–18°C during the peak summer months and maintain a very high humidity of about 95 per cent throughout the year even when the atmospheric relative humidity falls below 20 per cent. In peak winter months also the average maximum temperature of cool chambers remains about 5°C less than the average maximum ambient temperature. These chambers are ideal for short-term storage of fresh fruits. It has also been noted that the ripening process in the cool chamber is uniform and fruits are much firmer compared to those ripened under ambient conditions. In fruits like ripe mangoes in summer, oranges in winter and ber in spring the storage life is increased to 8, 27 and 12 days respectively in cool chambers compared to 4, 7 and 5 days respectively in ambient condition (Roy and Khurdiya, 1983). Once these cool chambers are set up by the small fruit growers they can build up a few days' stock before despatching them to the wholesale market, in this way the growers can a void the clutches of the middleman and need not have to make any distress sale. The cool chambers do not require any energy and would go a long way in solving the storage problem of fruit crops.

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